COMBUSTION

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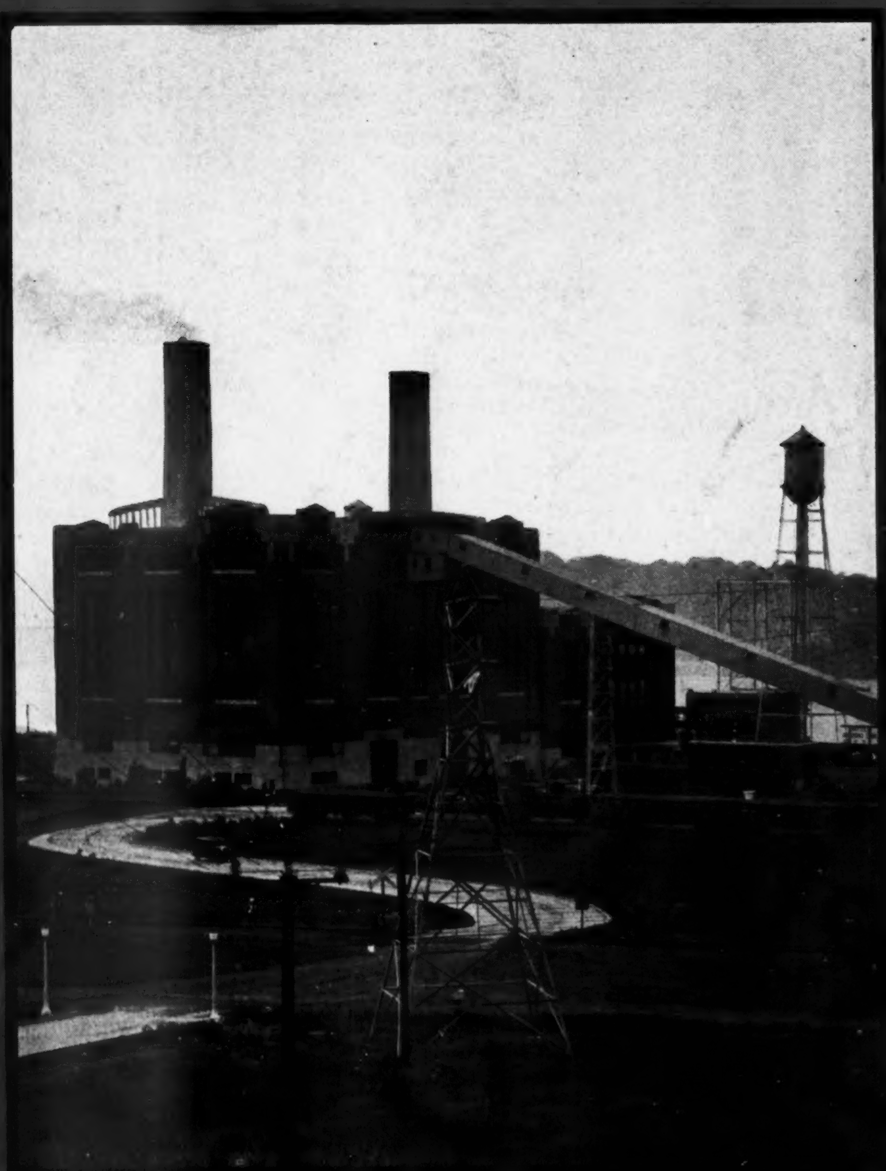
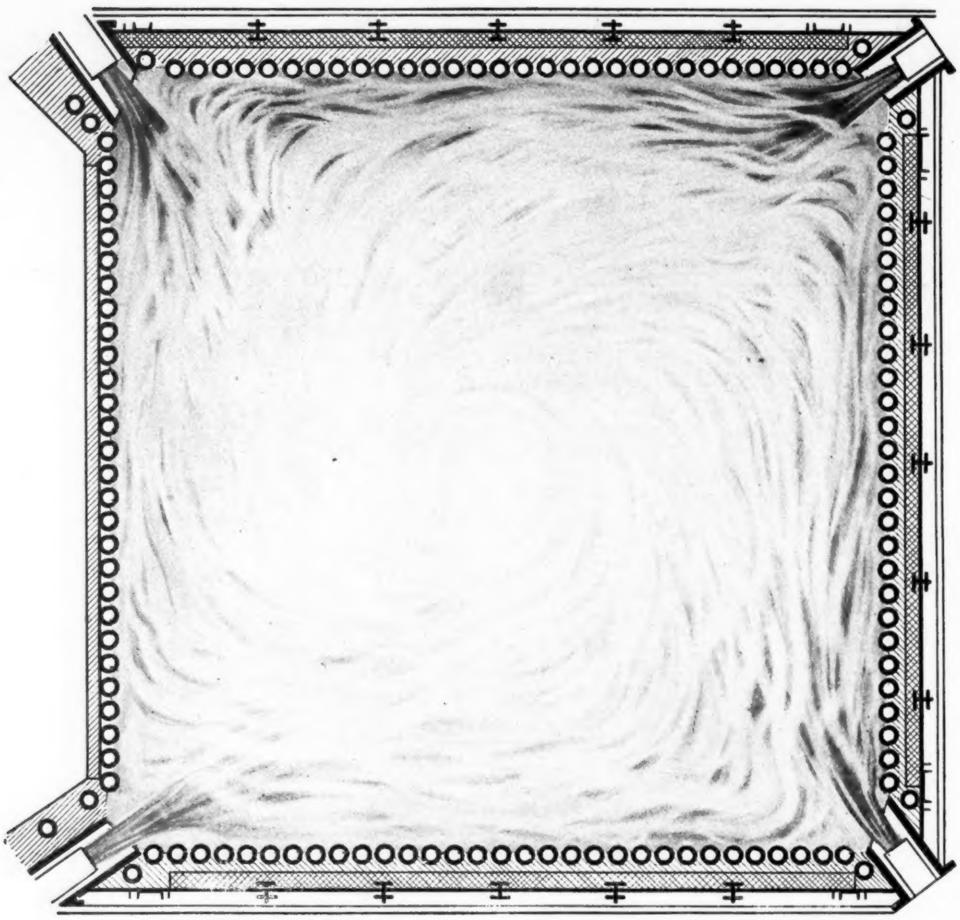


GRAND TOWER STATION, CENTRAL ILLINOIS PUBLIC SERVICE CO.

Tangential Firing of Gaseous and Liquid Fuels
By OTTO de LORENZI

Hydrogen Ion Determinations in the Steam Plant
By C. E. JOOS

OTHER ARTICLES IN THIS ISSUE BY
COMFORT A. ADAMS • C. H. S. TUPHOLME • J. A. KEETH • DAVID BROWNLIE



Plan view of furnace showing cyclonic action and turbulence resulting from corner-tangential firing. Note that the flame completely fills the furnace.

CORNER FIRING

the most efficient method of firing ANY fuel or combination of fuels...coal, oil or gas

The corner-tangential system of firing, developed by Combustion Engineeering Corporation for use in conjunction with completely water-cooled furnaces, is being used with conspicuous success in plants which exemplify the most advanced practice of today. Equally adaptable to coal, oil or gas fuels, used singly or in combination, the corner-tangential system assures rapid and complete combustion with high CO_2 and correspondingly high efficiency, in a minimum of time and space.

* * *

This method of firing is fully described in the new Combustion Steam Generator Catalog, copies of which are now available.

Leading industrials and public utilities now using corner firing:

- Ford Motor Company, Fordson
- New York Edison Co., Hell Gate
- New York Steam Corp., Kips Bay
- Philip Carey Mfg. Co., Lockland
- Solvay Process Co., Syracuse
- National Enameling & Stamping Company, Granite City
- Bethlehem Steel Co., Johnstown, Sparrows Point and Lackawanna
- West Virginia Power and Light Company, Boncar

COMBUSTION ENGINEERING CORPORATION

200 MADISON AVENUE . . . . NEW YORK, N. Y.

COMBUSTION

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DEPARTMENTS

CHARLES McDONOUGH — *Business Manager*
CARL STRIPE — *Editor*
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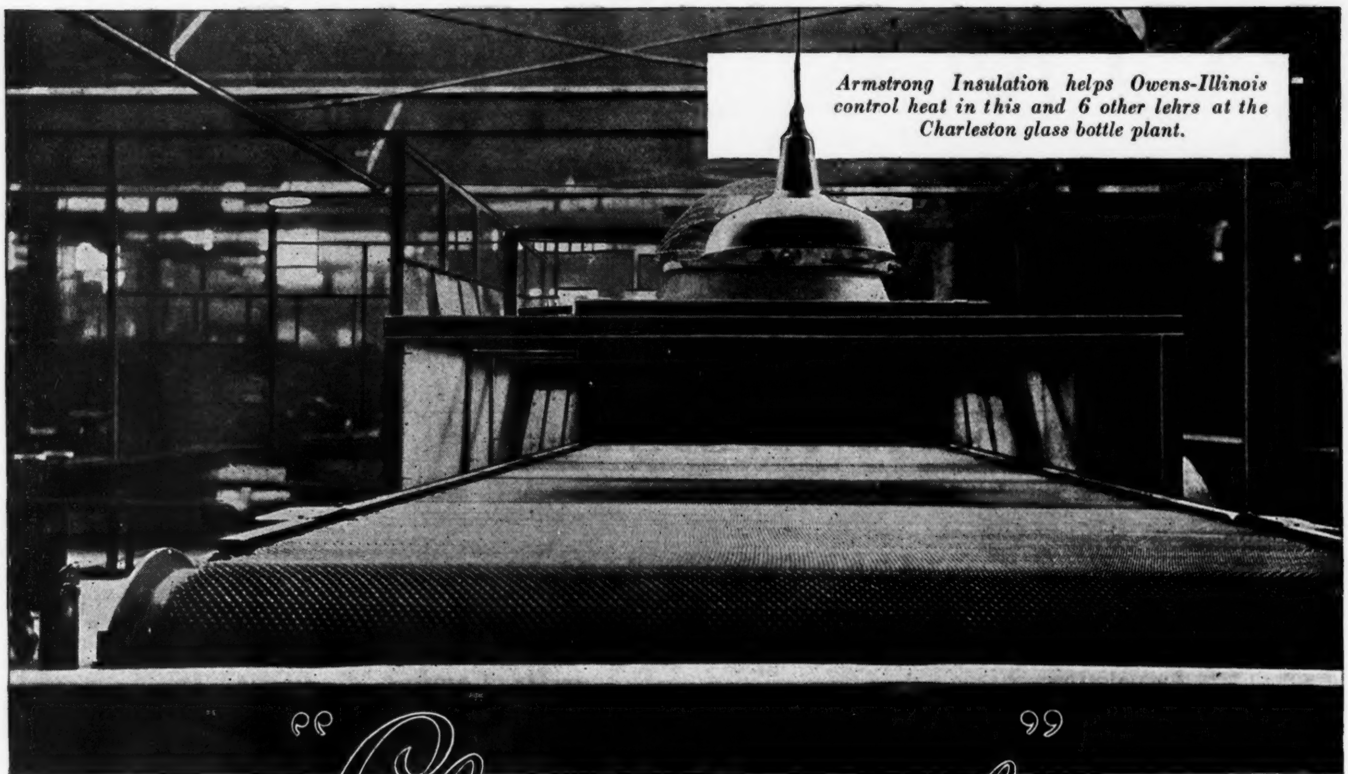

"Close control"

in OWENS-ILLINOIS LEHRS means ARMSTRONG INSULATION

BOTTLES as small as thimbles, as large as pails . . . bottles for drugs, bottles for pickles . . . round bottles, flat bottles, square bottles . . . these are the world-famous products of the Owens-Illinois Glass Company's factory at Charleston, West Virginia, one of the largest glass bottle plants in the country.

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Many other glass and ceramic plants, in addition to Owens-Illinois, have found Armstrong's and Nonpareil Insulating Brick ideal insulation for high temperature furnaces. The insulating efficiency of both brick is high—a factor which saves many times their cost in wasted fuel each year.

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Armstrong's (A) Product

Armstrong's and Nonpareil Insulating Brick

For Furnaces, Ovens, Kilns, and Lehrs

COMBUSTION

VOLUME 3 OCTOBER 1931 NUMBER 4

The Trend of Smoke Abatement

H. B. MELLER

THE type of anti-smoke ordinance in force in most of our larger cities was evolved as a compromise between the desire of a part of the public to have cleaner air, and the opposing attitude on the part of industry to the initiation of regulation that might go further than would seem, to it, desirable. To the credit of smoke abatement enforcement it can be said that there has been constantly increasing cooperation on the part of industry within the past decade, until, in the average city, atmospheric conditions are about as good as should be expected under existing laws, with limited forces of inspectors.

But the public is not satisfied. It is asking, not *cleaner* stacks, but *clean* stacks. It objects to the allowance of a limited amount of dense smoke and of an unlimited amount of light smoke. It recognizes the nuisance of ash, without being able to see it as it leaves the stack. City officials are criticized for permitting objectionable odors. That anti-smoke ordinances do not prohibit ash and fumes is not considered a good excuse—get the needed legislation, is the demand. This attitude is due to the general recognition of the fact that dense smoke is only one of the air contaminants that result from combustion, and the only one that is even partly regulated by law; and of the further fact that air pollution affects comfort and health.

Can this demand be met at this time, and legislation recommended that will be enforceable? It is plain that it cannot at once be met completely, but legislation can go part way, and steps can be taken toward the development of equipment that will gradually bring about the desired result.

Without attempting, in this limited space, to discuss different types of boiler-furnaces, stokers, fuels, etc., it may be said that, since smoke is a product of incomplete combustion, there will be visible smoke, more or less dense, until furnaces and methods are so perfected that combustion will be complete *at all times.* This result must be accomplished, not only on the test floor under competent engineering supervision, but in the average plant, large or small, the load constant or variable, using the logical fuel for the district. At present, for a large part of the country, that fuel is high volatile coal. It may be that the chemical engineer should be called upon to provide a practical catalyst, to insure that totally unburned carbon shall not leave the furnace.

The ash problem has been engaging the attention of many investigators. It will be necessary to have separators in all sizes, for the domestic chimney as well as for the large industrial stack, at such cost to the plant owner that a city will be justified in requiring separation to the degree that is economically practicable.

The two problems, namely, to secure complete combustion and to separate the ash, are essentially engineering problems. Manufacturers of boiler room and plant equipment need to go further than to satisfy existing city ordinances or to meet competition; they should fully recognize the public demand for clean air.

It can be predicted with sureness that anti-smoke ordinances will be made more drastic as the market affords fuel-burning equipment that will permit closer regulation. Our present laws are inadequate to cope with the situation that exists; to remedy the condition will require the active cooperation of research engineers, manufacturers of equipment, technical committees, such as the recently organized Pure Air Committee of the American Society of Mechanical Engineers, and smoke abatement enforcement officials.

H. B. Meller

Bureau Chief,
Bureau of Smoke Regulation, City of Pittsburgh

EDITORIAL

Coal Cleaning Comes to the Fore

THE coal industry consistently plays a defensive game.

Improvements in methods and practices are adopted only when absolutely necessary to survival.

Initiative is shown as a last resort and then merely as an expression of that primeval instinct—the fight for existence.

Whenever the coal industry finds that the rut in which it happens to be at the moment is no longer tenantable—then it grumblingly climbs out of that particular rut and, following its customary routine, it starts a new rut for itself.

For years various methods of coal cleaning have been known to the industry—methods for reducing the ash and sulphur content to a minimum. Nevertheless, the coal industry brings its raw product to the surface, loads it into cars, sells it "as is" and promptly forgets it. It is estimated that 95 per cent of our bituminous coal is shoved onto the market on this "take-it-or-leave-it" basis.

The ultimate consumer pays the freight on the coal and the ash. He unloads and bunkers the coal and the ash. He fires into his furnaces the coal and the ash. He finances the waste of fuel due to the poor combustion conditions resulting from excess ash, and finally—he shoulders the burden of ash removal and disposal.

Today coal faces a lean market. Not only does the entire industry suffer from the competition of hydro-electric, fuel oil and natural gas, but the average coal fields find difficulty in competing with those more fortunate fields which yield the better quality coals.

The poorest grades cannot be moved at any price.

The coal industry is up against a buyer's market; a market that cannot be dominated by the coal industry's favorite weapon—cut prices. The length of the present depression has long since dulled the edge of that particular weapon.

At present price levels, freight represents a large percentage of the total cost of coal to the ultimate consumer, and it is difficult to justify the purchase of low grade and high ash coals except for consumption adjacent to the mines.

This economic set-up makes cleaning at the mines practically imperative for all producers except those who market the highest quality coals.

Accordingly coal cleaning is now receiving the attention it has long deserved. The increasing adoption of cleaning at the mines will unquestionably widen coal markets, reduce waste in freight and in consumption, and raise the standards of a giant industry that is suffering from many maladies, particularly from chronic frozen initiative.

Corner Firing Applicable to a Wide Range of Fuels

FOR many years engineers have regarded as almost axiomatic the statement that,—"no method of firing is equally applicable to all fuels."

The wide variation in the burning characteristics of various coals presented a formidable barrier to any universal system of firing until pulverized fuel reduced all solid fuels to practically the same physical basis and zone cooling in the furnace eliminated the difficulties of ash fusion and agglutination.

Turbulence in the furnace has long been recognized as necessary for the best combustion conditions. Various mixing types of burners have been employed in an effort to secure this condition, but it was apparent that turbulence in the burner was but a means toward the desired end—turbulence in the furnace.

The all-important prerequisite to high combustion rates and high combustion efficiency is the complete filling of the furnace, from top to bottom, with the burning fuel, combustion air and the products of combustion—all in intense turbulence.

The introduction of corner firing provided, for the first time, the desired degree of turbulence—*in the furnace itself.*

In this issue of COMBUSTION is presented an important article on the application of corner firing to oil and gaseous fuels.

The applicability of corner firing in combination with all-metal water-cooled furnaces, to the entire range of commercial fuels, coal, oil and gas, proves the fallacy of that venerated engineering belief that no one firing method can meet all fuel conditions.

Hub of America in a Coal Mine

IN a strip coal mine, three miles northeast of Linton, Indiana, is being erected a marker to indicate the exact center of population as determined by the recent Census Bureau survey.

Thus the hub of the United States is located in a coal mine, an appropriate coincidence, which may be interpreted as symbolic of the fact that coal is the center of our national economic structure.

Despite the persistent threats of hydro-electric, diesel power, natural gas and fuel oil—coal is the focal point of our national existence. On it depend our basic industries, our transportation, our standards of living, our health, our comfort, and our well-being.

Again it is demonstrated that coal, our basic fuel, is consistently in the middle of things.

Tangential Firing of Gaseous and Liquid Fuels

By OTTO de LORENZI
Combustion Engineering Corporation, New York

Tangential or corner firing, a comparatively recent development, has been used principally in firing pulverized coal. However, installations have been made which demonstrate that this method of firing is equally suitable for gaseous and liquid fuel and that it possesses marked flexibility in that it permits the burning of any combination of these fuels simultaneously in the same furnace. This feature is of great advantage especially in industries where a low cost fuel, such as blast furnace gas, is available but the supply of which fluctuates and cannot be depended upon to meet steam plant requirements at all times. The author discusses the development of tangential firing with particular reference to its use in connection with blast furnace gas. Several installations are described and data are given on the results obtained.

UNTIL very recently, little serious thought was given to the design of burners and furnaces for gaseous or liquid fuels. The ease with which it is apparently possible to accomplish the mixing of the necessary combustion air with the gas or the finely atomized liquid fuel, is no doubt responsible for this neglect. However, the progress in the burning of pulverized coal was so remarkable, that the lessons learned were soon adapted and applied to fuels having similar operating characteristics.

The two principal gaseous fuels, available for use in the power plant, are blast furnace gas and natural gas. The use of producer and coke oven gas, as boiler fuels, is limited. However, the principle, which is to be discussed, may also be applied to either of these two latter fuels.

Blast furnace gas has a heat content of from 85 to 105 B.t.u. per cu. ft. It is known as a "lean" gas because of the large amount of inerts it carries. Because of this quality it is slow to ignite and difficult to burn quickly and completely.

The gas as it leaves the "top" is hot and contains a considerable amount of dust. In order to separate out some of this, it is passed through dust collectors. The dust, which has been removed, is then sintered and returned to the furnace as a part of the "charge." Because of the lowered dust content, the gas may be used under boilers or in stoves having large flues. In some plants the gas is subjected to additional cleaning in scrubbers after having passed through the dust collectors. This serves to increase the interval between cleaning periods of the stoves, and also permits the use of the more efficient small-checker flue.

When gas, which has been cleaned as described in the preceding paragraph, is used as a boiler fuel, considerable dust is deposited along the mains. Large quantities also pass through the burners and into the boiler furnaces. The burners nearest the blast furnace will receive the coarser particles, while the more distant ones will receive the finer dust. The building up of this dust, on the hearth and the walls of the boiler furnaces, is an adverse factor and such accumulations must be frequently removed. If they are not removed, sintering will occur in time. Their removal then is very difficult as they are extremely hard and adhere tenaciously to the refractory surfaces of the furnace.

The sintering of blast furnace gas dust, in boiler furnaces, has led to the installation of equipment for thoroughly cleaning the gas. It may be washed in a spray tower or it may be dry cleaned. When a spray tower is used, the gas is cooled to approximately 80 deg. fahr. and thus there is a loss in sensible heat content. In addition to this, the gas is saturated with water vapor. However, with properly designed washing equipment, it is possible to reduce the dust content to as low as 0.01 grains per cu. ft. In the case of dry cleaning in whirlers, the dust content is reduced to about 1.75 grains per cu. ft. and there is practically no loss in sensible heat. Even though there is a loss in sensible heat, it has been found profitable to wash the gas, as furnace cleaning and refractory maintenance is reduced to a minimum.

Burners for blast furnace gas have passed through many successive stages of development. The earlier ones consisted of pipes or rectangular boxes through which the gas was introduced into the furnace. The air for combustion was drawn in by furnace draft through openings around the burner nozzle. Because of lack of turbulence and

means for regulating the air supply, to correspond to the variations in gas supply, a high percentage of excess air was required. Improper mixture of the air and gas resulted in secondary and continuous combustion, extending through the entire boiler setting. The efficiency of steam generation was low, but this was looked upon as a necessary evil. However, as fuel costs began to advance, thought was given to designs which would serve to increase the combustion efficiency when burning this by-product fuel. Experiments immediately indicated that the efficiency of the burner could be increased, by securing proper mixture of the gas with the air for combustion. This led to the present-day type of burner in which the gas and air are broken up into small streams which intermingle on entering the furnace. In order to secure additional turbulence and positive regulation of the air quantity,

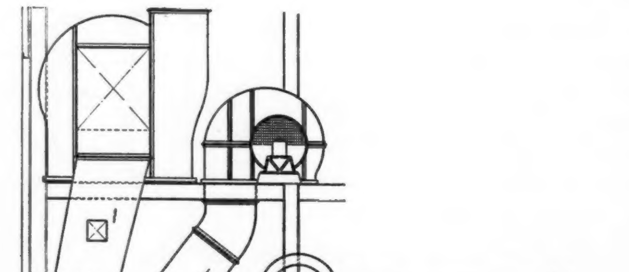

Figure 1

the latter is supplied to the burners under pressure. Thus, with these newer types of burners and proper automatic regulation, it is possible to operate with from 20 per cent to 25 per cent excess air in the furnace.

With the use of the improved burner design, it immediately became apparent that best results were obtained when the furnaces were not pushed too hard. Therefore, to secure desired output, it became necessary to increase the furnace volume so as to take full advantage of the burners. While a large furnace volume is essential to good combustion, the shape and disposition of the furnace should be such as to make it entirely effective. The dead spaces should be eliminated, as far as possible, so as to minimize pulsations. From 2 to 3 cu. ft. of volume should be provided per developed horsepower. The burners should be so placed that a minimum flame travel of 15 ft. is provided for. To sustain ignition, refractory surfaces must be placed in the immediate vicinity of the burners. Particular care must be exercised in the design, so as to provide for the easy removal of dust accumulation from all parts of the furnace and setting.

The first step in securing the results outlined in the preceding paragraphs was to increase the turbulence of the gas and air streams as they leave the burner. Even under this condition, the mixture is slow to ignite and has a tendency to long flaming. The reason for this is that the gas contains a large percentage of inerts, and in order to speed up ignition, it is necessary to bring the gas and air together very rapidly. This is most easily accomplished by providing additional turbulence in the furnace itself, after the gas and air mixture has left the burners. The additional mixing or turbulence will speed up combustion and thereby reduce the furnace volume requirements. It will also eliminate the possibility of stratification and insure continuous mixing of the gas and air during the combustion process. To accomplish these results, it is necessary to provide a furnace construction which will prevent or minimize the possibility of sintering, of any dust accumulations which may occur. Furnace conditions will be further stabilized by the use of highly preheated air which will act to accelerate ignition.

These principles have been given a thorough trial over a period of several years. The results have been even better than anticipated, in that predicted efficiencies and capacities have been continuously exceeded.

Two new types of steam generating units embodying these principles were put into operation in the Sparrows Point Plant of the Bethlehem Steel Company in 1928. The primary fuel was blast furnace gas, while pulverized coal was provided as auxiliary, to take the peaks and carry the load when sufficient gas was not available. The main difference in the design of these units, over that which was the accepted standard, was the manner in which the gas was introduced and burned in the furnace, and the fact that the furnace was completely water cooled. When fired with blast furnace gas, the capacity of each unit was specified as 90,000 lb. of steam per hour, at an efficiency of approximately 80 per cent.

The furnace of each unit is approximately 14 ft. square and 25 ft. high, having an effective volume of 5000 cu. ft. The four sides and roof are completely covered with water cooled surface. A water screen forms the bottom of the furnace, through

which the products of combustion pass before entering the boiler section of the unit. The amount of steam generating surface exposed to direct furnace radiation is 2034 sq. ft. The total amount of steam generating surface contained in the unit is only 8350 sq. ft. The coal and gas burners are placed near the top and in the four corners of the furnace. They are so directed that the fuel and air streams issuing from them are directed, horizontally along a tangent, to a small imaginary circle lying in the center of the furnace. This method of directing the fuel and air streams imparts a rotary motion to the mixture in the furnace. Turbulence is secured, and intimate mixing of the fuel and air is obtained. This so-called "tangential firing" is the most important feature of these units, and is a principle which had been overlooked in the design of the older types of burners and furnaces.

At the guaranteed evaporation of 90,000 lb. per hour, the heat liberation in the furnace is approximately 26,000 B.t.u. per cu. ft. per hr. Evaporation rates up to 120,000 lb. per hr. have been carried with ease, and the corresponding liberation is in excess of 36,000 B.t.u. per cu. ft. per hr.

The operation of these units demonstrated that combustion was definitely speeded up and the flame shortened to the extent that no traces of CO are present in the gases after they have passed through the lower furnace water screen. The heat absorption of the water wall surface is uniform, and is constantly maintained at a high point by the revolving column of gases, the sweeping action of which serves to prevent the formation of comparatively stagnant and cool gas layers along the walls. In addition to this, the efficiency of the wall as a heat absorbing medium is maintained at a high point, because any dust or slag accumulations, after a time, fall off and drop into the ash pit. Sintering is eliminated because a relatively low furnace temperature is maintained by the high heat absorption efficiency of the walls. While tangential firing is responsible for the manner in which this unit performs, the use of highly preheated air must not be overlooked. The temperature of the air, leaving the heater with gas firing, reaches 400 deg. fahr. It is therefore not necessary for the furnace to supply all the heat required for the ignition of the fuel. Under these conditions, the resulting furnace temperatures are higher than if cold combustion air is used. Where washed gas saturated with moisture is used, hot air is particularly advantageous, as it accelerates ignition.

A unit similar to the ones installed at Sparrows Point is illustrated in Fig. 1. It will be seen immediately that the furnace is designed as an integral part of the boiler and that both an economizer and air preheater are provided.

The success of this initial installation has been responsible for the general use of this type of unit in several other plants. To improve operation a few design changes were made. The main ones were inverting the furnace, and firing at the bottom corners. The modified type of unit is shown in Fig. 2. Here again the furnace is completely water cooled. The convection bank in the lower portion of the furnace has been replaced by a water screen, consisting of a single row of tubes spaced on relatively wide centers. The ash pit is shallow and sufficiently shaded to prevent sintering of the

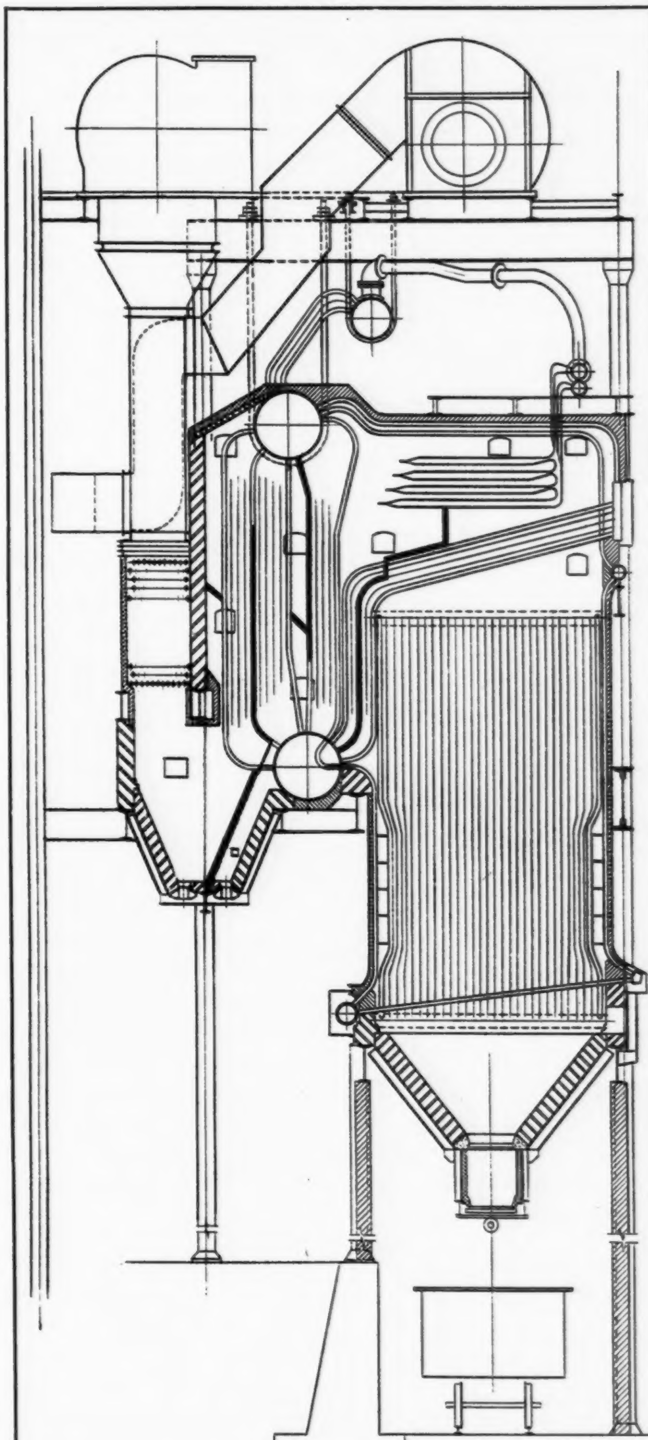

Figure 2

dust which may accumulate. The coal and gas burners, arranged for tangential firing, are located in the lower corners of the furnace. The products of combustion pass upward through the furnace and enter a screen consisting of four rows of tubes. The superheater is protected from the full

furnace temperature by this screen. After leaving the superheater, the gases make three passes over the boiler section and then pass through the economizer and air preheater on their way to the induced draft fan and stack.

The principal reason for inverting the furnace is to eliminate the possibility of sintering the dust accumulations. In the previous design, the products of combustion sweep over the dust accumulations in the settling chamber after passing through the lower convection bank. Thus if the unit is operated at excessive rates, the temperature below the screen becomes sufficiently high for sintering to occur. In the revised design, when once the dust is separated from the products of combustion, it cannot come in contact with them again and any chance of sintering is thus eliminated.

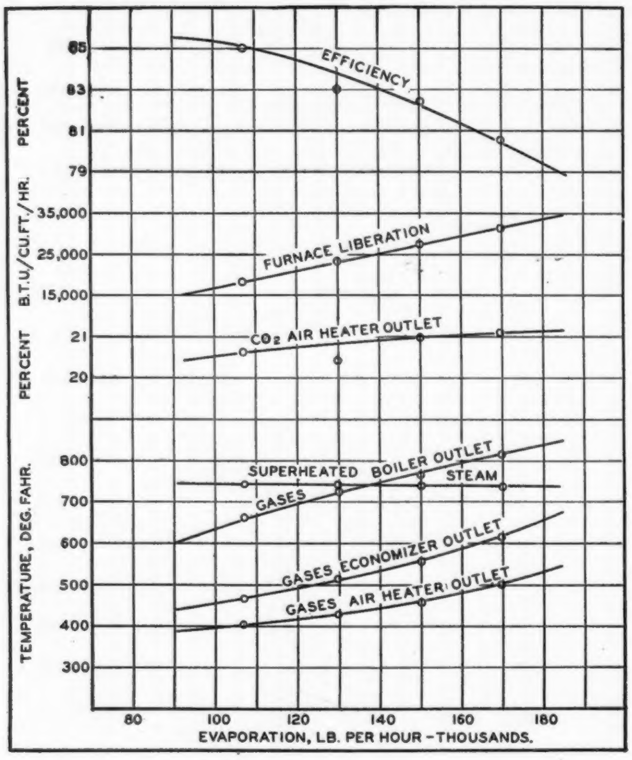

Figure 3

In November, 1930, two units of the revised design were put into operation at the Cambria Plant of the Bethlehem Steel Company. They have been operated for long periods of time with washed blast furnace gas. No difficulty has been experienced in lighting up or in maintaining good ignition during operation, even though the gas is saturated with water vapor.

In the case of the Cambria units, the furnace width is 16 ft., while the height is 19 ft. 10 in. The effective furnace volume is 8000 cu. ft. The heat absorbing surface exposed to direct furnace radiation is 2215 sq. ft. The boiler surface is 12280 sq. ft., while the superheating surface is 2651 sq. ft. A fin tube type of economizer, containing 5382 sq. ft. and a 12000 sq. ft. plate type air preheater are also provided. The arrangement of baffling and the location of the various pieces of equipment are well illustrated in Fig. 2.

When burning blast furnace gas, these units were guaranteed to operate at an evaporation of 125,000 lb. of steam per hr., with an efficiency of 81.5 per cent. Tests have been made at an evaporation of 170,000 lb. per hr. with a resulting efficiency of 80.7 per cent. The efficiency obtained at the guarantee point was 84 per cent.

These results were obtained by the use of a very clean gas containing only 0.005 to 0.01 grains of dust per cu. ft., of which the following is a typical analysis:

	Percent by Vol. at 60° F. Dry	Percent by Weight Dry	Percent by Weight Wet—As Fired
CO_2	9.4	14.18	13.73
CO	30.2	28.99	28.07
H_2	1.3	0.09	0.09
N_2	59.1	56.94	54.95
H_2O	17.6*	0.0327**	3.16

	Per Cu. Ft. at 60° F.	Per Lb. Dry	Per Lb. As Fired
Heat value B.t.u.	102	1326.4	1284.5

* Grains per cu. ft. at 60 deg. fahr.
** Lb. per lb. of dry gas, 0.0111 lb. as vapor, 0.0216 lb. as entrained liquid.

The performance of this unit, during the test, is clearly shown in the chart, Fig. 3. At the maximum rating, the heat liberation in the furnace does not exceed 32000 B.t.u. per cu. ft. From this it will be seen that the furnace is conservatively rated in the light of past performance. In a great measure this reduced rate of heat liberation is responsible for the high test results, as well as the high operating efficiencies obtained with these units.

The completeness of combustion, with a relatively low percentage of excess air, is the result of the intense turbulence obtainable with tangential firing. The measure of the uniformity of results is the relatively flat and high percentage CO_2 curve. The results, as plotted, indicate the CO_2 content of the gases as they leave the air preheater and therefore includes the leakage air, which is present, in varying amounts, in all installations.

The value of this type of unit, as a saver of heat dollars, is illustrated by the high and consistent efficiency curve. The range of this curve is from 85 per cent at 107,000 lb. per hr. to 80.7 per cent at 170,000 lb. per hr.

In order to facilitate lighting up, steam atomizing oil burners were installed in the four corners. Due to the fact that fuel oil was obtainable at a very desirable figure, it was decided to temporarily operate the units with this fuel instead of pulverized coal. The demand for steam was considerably below normal. With the small steam atomizing burners in service, evaporation rates up to 40,000 lb. per hr. were carried. The rate of heat liberation, corresponding to this evaporation, is approximately 8000 B.t.u. per cu. ft. This serves as a good illustration of the stability of tangential firing, in an all water-cooled furnace, at rates of heat liber-

ation that are lower than ordinarily reached in normal daily operation.

During the past summer, a large quantity of by-product coal tar was available at this plant. This tar was heated and fed to the furnace through steam atomizing burners. Rates of evaporation up to 100,000 lb. per hr. have been carried, with exceptionally good furnace conditions.

Units almost identical in design have been installed in the Lackawanna plant of the Bethlehem Steel Company. These units are operated with a washed gas containing from 0.1 to 0.2 grains of dust per cu. ft. With this fuel considerable difficulty was experienced due to plugging of the original burners furnished with the unit. Modifications in design have served to increase materially the interval between burner cleaning periods, and ratings, above those guaranteed, are consistently maintained. During periods of low steam demand, these units have been operated at an output varying from 25000 to 50000 lb. of steam per hr. The fuel was blast furnace gas and the average liberation was 6500 B.t.u. per cu. ft. of furnace volume per hr. This performance again serves to illustrate the stability of conditions obtainable with tangential firing, and it is believed that this establishes a precedent for burning fuel as lean as washed blast furnace gas at such a low rate of liberation, in an all water-cooled furnace.

Units designed for high efficiency, with blast furnace gas as the primary fuel, must of necessity have economizer as well as air preheater surface, in conjunction with the steam generating section. The elimination of the economizer would serve to greatly reduce the efficiency obtainable, for the heat recovery possible in the air preheater is relatively low. The low recovery is due to the difference in weight of the products of combustion and the weight of air required to burn the fuel. With blast furnace gas, there are roughly 2 lb. of products to 1 lb. of air. While with coal, there are approximately 12 lb. of products to 11 lb. of air.

Where units are designed for use with fuels other than blast furnace gas, it is possible to proportion the steam generating and air preheater surface so that the economizer may be omitted. The recently developed Combustion Steam Generator is of this type and is illustrated in Fig. 4. Incorporated in this unit are many of the points discussed in this article. The furnace is completely surrounded by water-cooled surface capable of high rates of heat absorption. The fuel is fired tangentially from the four lower corners of the furnace. Water screen protection is provided so as to prevent the slagging of the accumulated ash in the pit. The superheater is screened from the direct radiant heat of the furnace by four rows of tubes, and is located above the furnace. A by-pass damper is provided so that a portion of the products of combustion, leaving the furnace, may be short circuited around the superheater. In this manner, it is possible to obtain a relatively flat superheat curve, over a range of ratings, without the necessity of resorting to multiple superheaters and intervening reheaters.

The convection surface of the unit consists of three-inch tubes, over which the gases make one pass. Suitable baffles are provided to give the maximum possible heat recovery. In addition to the steam generating surface, there is also provided air preheating surface. The amount of this surface will usually be determined by the overall efficiency desired.

The adaptability of units incorporating tangential firing, in fully water-cooled furnaces, has been demonstrated in the installations at Sparrows Point, Johnstown and Lackawanna. Washed blast furnace gas, with its characteristics of high moisture content, difficult ignition, slow burning, long flaming and varying dust content, has been burned successfully at rates varying from 6000 to 36000 B.t.u. per cu. ft. per hr. With this fuel, the resulting efficiencies are as high, if not higher, than those previously possible to obtain. Pulverized coal, fuel oil and by-product tar have also been burned, with

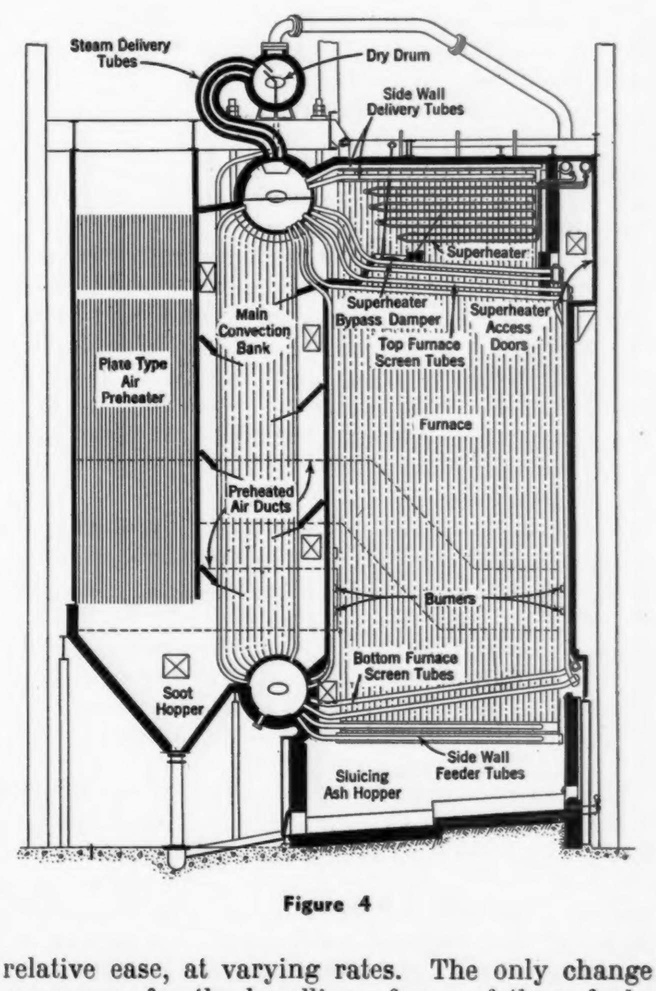

Figure 4

relative ease, at varying rates. The only change necessary, for the handling of any of these fuels, consisted in changing the types of fuel nozzles, in the furnace corners. If it is so desired, it is possible to permanently install burners to handle coal oil and gas, and these fuels may be burned simultaneously or separately as desired. Changing from one fuel to another may be accomplished on very short notice.

In different sections of the country, the composi-

(*Continued on page 21*)

Address to the American Boiler Manufacturers Association

By Dr. COMFORT A. ADAMS

Professor, School of Engineering, Harvard University, Cambridge, Mass.

This address was presented at the 43rd annual convention of the American Boiler Manufacturers Association, Skytop Lodge, Skytop, Pa., May 25, 1931, and has just recently been released by the Association. It is an unusually comprehensive discussion of the various methods of welding and their respective advantages and limitations. Dr. Adams lays particular stress on the importance of the X-ray test method prescribed in the recent A.S.M.E. Code for Welded Boiler Drums and takes the stand that, in their own interest, boiler manufacturers should welcome this and the other restrictions imposed by the Code.

MR. President, Mr. Secretary of the Welding Committee, and members of the American Boiler Manufacturers' Association. You have been told that I come from the most high-brow institution in America. I consider this a compliment. To my mind it means the institution where young men are taught to think for themselves and where they are given a foundation on which to build their thinking processes.

It just happens that I have had a rather broader scientific training than most engineers and it is undoubtedly a fact that such success as I have had in the industrial field has been wholly due to that foundation and to the habit of thinking for myself or solving my own problems. This may perhaps explain to you the general trend of my thought in the welding field as shown by what I shall have to say on that subject.

You are boiler manufacturers for the most part and have been dealing with mechanical problems. It is even possible that some of you may look upon the welding problems as just another mechanical problem, but as a matter of fact, there is hardly any process in industry that involves so many fields of science as welding does. These are briefly chemistry, metallurgy, and physics, particularly with reference to electric arc welding.

Moreover, owing to the very high temperatures involved, there are certain phases of both the metallurgical and physical side of the problem which are decidedly new to the metallurgist. To put the picture in another form, the number of variables involved in the welding process is larger than in almost any other field with which I am familiar. So much in the way of general introduction.

I have found that even most of those who are vitally interested in and practically concerned with welding are familiar only with the practical side of some one or two branches of the field. It would seem desirable, therefore, to present a very brief review of the various types of welding that have been and are being employed.

My own memory goes well back to the time when the only welding process was what is commonly called forge welding or hammer welding. The first step into the new field was resistance welding, invented by Elihu Thomson back in the middle eighties.

Resistance welding consists of the welding of two pieces of metal together, the surfaces of which have been heated by an electric current. For example, take two pieces of wire or two rods or two tubes of metal with their surfaces well fitted to each other, butt them together, and pass a current through them. The current meets with resistance all through the metal, but the resistance at the surfaces in contact is tremendously higher than that in the solid metal. Therefore, when a heavy current flows, the contact surfaces will be heated to a much higher temperature than the body of the metal, and if that heat is developed rapidly enough, they will be raised to the welding temperature before the remainder of the metal is heated to any considerable extent. When the welding temperature has been reached, further pressure is applied, the upset takes place and the metals are joined. This process is one kind of pressure welding, and is wholly comparable to forge or hammer welding. It was employed first in the welding of copper wires in electric manufacturing concerns where, in the winding of electrical machinery of various sorts, it was desired to obtain a continuous conductor without mechanical joints.

The application of this method was rather limited

for many years, partly because industry had not developed to the point of appreciating its possibilities. Moreover, the method as described above which is now called upset welding, or straight resistance welding, has distinct limitations, particularly in its application to large cross-sections. It is difficult to get two large surfaces so nicely fitted that the contact resistance of the joint will be uniform over its area, since this is necessary in order to have the heat distribution uniform. This difficulty is further accentuated by the fact that the outer surfaces of the parts where they are gripped in the jaws of the machine do not always bear the same geographical relation to the surfaces to be welded. It is thus very difficult to make an upset weld on parts of large cross-section.

As a result there was developed a modification of this method known as flash welding, in which the two parts to be welded are gripped in the jaws of the machine, brought into light contact, and then separated very slightly. This establishes what may be termed an arc between the two parts. The surface metal is raised to a very high temperature, and burns or oxidizes in the air, the burning metal being thrown off in a shower of sparks which give rise to the term flash. This flashing process is continued until the two surfaces are brought to exact parallelism and until the surface temperatures are seen to be uniform all the way around the joint. As the metal burns away, the ends have to be moved slightly to maintain the very short gap between the parts. When the desired condition is reached, the current is shut off, pressure is applied and the weld completed.

There is probably a very thin layer of practically molten metal on the surfaces of the joints before the upset takes place. In any case, there is at the surface, or back of it, a thin layer of plastic metal at welding temperature. If there is any oxide between the joints at the time the push-up is made, its greater fluidity allows it to be squeezed out and the weld should be, and usually is, perfect throughout the whole cross-section.

Flash welding is readily adaptable to all sorts of shapes and sizes and there is no apparent limit to the size of the sections which can be welded. In the early days, conservatism, timidity, and perhaps lack of capital, kept the application of this method to relatively small parts, but it is now common practice to weld cross-sections of 60 square inches or more. As a matter of fact, I would gladly undertake the construction of a machine to weld several hundred square inches of cross-section—for example, two tubular sections of a boiler drum of any reasonable diameter and several inches in thickness.

A few figures may be helpful in this connection. For satisfactory flash welding, the power consumed during the welding should be at least 15 kilowatts per square inch of cross-section, although a larger amount of power would be better and would do the work more quickly. Thus, if you wish to weld two tubular drum sections together with a cross-section of 1500 square inches, a safe margin of power would be 30,000 kilowatts, and the weld could be made in about one minute or less. As this would be single-phase power, it could not be taken from one phase of a polyphase system, but would have to be supplied by a polyphase motor driving a single-phase alternator. Moreover, as the duration of the current flow is so small as compared with the time required to arrange the parts in the machine, the generator could be very much overloaded for these short periods and it would not be necessary to have a generator of more than eight or ten thousand kilowatts continuous rating. Even the size of the motor could be reduced in the same way and the drafts of power on the system could be averaged up by the use of a flywheel on the motor generator set.

It is obvious that the cost of such equipment would be enormous and that this expenditure would not be warranted except in case many such welds were being made every day. However, if these welds were being made with sufficient frequency to reduce the capital charge on equipment, the time and labor required would be small as compared with that of any other known process.

The cost of such a motor generator set would be about $200,000 without the transformer for stepping down voltage to the very low point required for the welding process. This does not include, however, the cost of the mechanism for handling the tubular drum sections during the welding period or the means for pushing them together with pressure enough to complete the weld.

Another common variety of resistance welding is known as spot welding, where two sheets are overlapped and gripped at the overlap between two electrodes under considerable pressure. When a heavy current is passed from one of these electrodes through the overlapped sheets to the other electrode, heat is developed at the contact surface between the two plates. When this has reached the desired point, further pressure is applied and the weld completed. The current is confined largely to the spots where the grip takes place because that is the lowest resistance path. The pressure is sufficient to leave considerable indentations at the points where the electrodes are applied, particularly in the case of thick plates, where the pressure must be very great.

As it is very difficult to apply this process to heavy plates, it is rarely used with plates thicker than ⅜ or ½ inch—in fact, most spot welding is done on much thinner plates than this.

In one type of spot welding known as projection welding, slight projections are made in one of the sheets at the points where the welds are desired. These projections can be made in thin sheets by merely denting the plate with a punch, thus pushing out a projection on the other side. In this case, relatively large flat electrode surfaces can be used without spreading the current flow beyond the projection points: namely, the latter serve as concentration points for the current which does the

welding. This eliminates the dents or marks usually left by the electrodes in the straight spot welding process.

Another variety of resistance welding is known as seam welding, in which the overlapping edges of two thin plates are passed between two electrode rolls continuously, the current and speed being so adjusted as to give the proper welding temperature without burning.

Another application is in tube welding, where a flat strip is rolled up into cylindrical form and passed through the welding throat, which consists of supporting rolls on the under side and two electrode rolls, one on each side of the seam cleft, which usually constitutes a square edge butt joint, the current passing from one electrode roll across the seam cleft to the other at the same time that pressure is being applied. This method is readily applicable to any comparatively thin-walled tubing, although it has been applied with some success to wall thickness up to ¼ or even ½ inch. The difficulty in this latter application is exactly the same as in the case of straight upset welding: namely, the difficulty in having the two edges of the seam cleft fit so perfectly as to give a uniform distribution of heat and pressure.

At about the time of the invention of the resistance welding process, say forty-five years ago, the carbon arc process was developed. In this process an arc is struck between a carbon electrode and the joint to be welded. A welding wire or filler wire is then fed into the arc and fused into the joint. It is exactly like the gas welding process except that the heat is developed by the arc rather than by a gas flame. The temperature of the arc, however, is very much higher than that of any gas flame. The joint is usually prepared in the form of a groove between the two plates and the welding wire fused into this groove. It is possible, however, in the case of thin plates to butt the edges squarely together and apply the arc without any filler rod, thus fusing the two edges of the plate together. In the case of slightly thicker plates, even up to ½ inch in thickness, it is possible to fuse half way through from one side and half way through from the other thus completing the weld. This thickness is, however, about the limit, as it is difficult to fuse the edges of the plates with certainty and uniformity more than ¼ inch deep.

Next came the gas welding process and the metallic arc welding process. In the latter process, the welding wire itself is used as one of the electrodes, an arc is struck between this electrode and the joint, and the wire or rod fused into the prepared groove between the two edges to be welded.

In the gas welding process the heat is developed by a gas burning in commercially pure oxygen. The gas is usually acetylene, which is superior to any other gas for this purpose. In this process the heat is not as intense as in the arc and if the parts to be joined are of any considerable thickness, it is necessary to pre-heat the joint either with the oxyacetylene flame itself or by some cheaper source of heat. In any case, it is necessary to raise the surfaces of the joint to the welding temperature by playing the flame on these surfaces before starting to fuse in the welding wire. In the case of arc welding, the intensity of the heat at the end of the arc is sufficient to fuse the surface metal at this point no matter how thick the plates may be. In order to do this satisfactorily, however, it is necessary to hold a short arc so as to concentrate the heat on a small area of the plate edge. If the arc is too long, it spreads over a larger area and there is insufficient penetration. I have seen many arc welds where this was the case and where there was no bond between the deposited metal and the surface of the joint.

The heat developed in the arc may be divided up into three parts; that at the positive end, or anode, that in the arc stream, and that at the negative end, or cathode. If the arc stream is short, it consumes a relatively small amount of the total heat. The anode heat is greater than that of the cathode. It has on this account been common practice to make the plate positive in ordinary bare arc welding, since it obviously takes more heat to fuse the surface of a large mass of metal than to fuse the end of a small electrode wire.

If, however, an alternating current is used when the polarity reverses 120 times a second, it is obvious that the average heat is the same at the two ends of the arc. It is nevertheless possible to use alternating current with bare electrodes, although much greater care is necessary to obtain proper penetration.

One of the limitations of bare electrode welding is due to the fact that most metals, particularly steel, at the high temperatures involved oxidizes very rapidly when exposed to the air; they also absorb nitrogen from the atmosphere. Thus as the metal passes across the arc from the electrode to the joint, it becomes contaminated in this way and it happens that both oxide and nitride of iron are highly undesirable in a weld, producing brittleness, and if in sufficient quantities, reduced tensile strength. On this account, hundreds of methods of protecting the metal from the atmosphere have been employed. Most of them come under the head of coated or covered electrodes. The coated electrode is usually understood to be one with a relatively light or thin coating, usually of a fluxing nature, the intention being to flux out the impurities and have them rise to the surface. Most of these coatings are relatively useless, since the rate at which the metal cools is in most cases such as to preclude the expected operation. In other words, the impurities are trapped in the cooling weld metal.

Covered electrodes are provided with a much heavier coating, the function of which should be chiefly to provide a protective atmosphere or a protective gas envelope, preferably of a reducing nature, between the arc and the air. There are many such coverings of varying degrees of effectiveness.

Some of the older covered electrodes, which might be designated as slag-covered electrodes,

produce a considerable molten slag which floats on top of the deposited metal. It was assumed by the original inventor of this type of electrode that this molten slag would flow from its source on the electrode wire around the arc, forming a complete slag envelope therefor, but as a matter of fact, it does not seem to function in the expected way, as oxides and nitrides are almost invariably found in the deposited metal.

Another function of the slag type of electrode lies in the fact that the molten slag protects the deposited metal from the air while it is cooling, reduces the rate of cooling slightly and in that degree makes more probable the purging of the deposited metal of any slag inclusions.

Another method of protecting the metal in its passage across the arc consists in projecting a stream of combustible gas, usually hydrogen or of the hydrocarbon variety, around the arc, thus providing a reducing atmosphere to accomplish the same result as from the electrode coverings. This process is commonly known as the shielded-arc process.

Another variety which comes in the same class is the atomic hydrogen process, in which an arc is established between two tungsten electrodes and a jet of hydrogen projected through the arc. The heat of the arc breaks up the hydrogen molecules into atoms, which recombine after they have passed through the arc, thus giving up the heat that they absorbed from the arc in what practically constitutes a flame of hydrogen burning in hydrogen, with a temperature lying somewhere between that of the arc itself and the oxy-acetylene flame. In other words, this apparatus constitutes a torch which is used in exactly the same way as an oxy-acetylene torch.

One advantage of this torch, as well as of the gas torch, is that it is much easier to control the heat on delicate work by moving the flame with respect to the work. It is obvious that after the atoms of hydrogen have joined to form molecules again, they finally burn in the surrounding air. This process provides an intensely reducing atmosphere and when properly applied assures the absence of oxides and nitrides in the weld metal.

It should be noted in this connection that the oxy-acetylene flame when properly adjusted produces its own protective envelope for the molten metal in the form of the products of combustion. In fact, it is entirely possible to adjust the torch so as to supply a slight excess of acetylene, which means a reducing atmosphere. This is in marked contrast to the arc welding, which requires some special provision to produce this result.

The above outline of welding processes is not at all comprehensive, as there are many subdivisions of each type. Moreover, all of these processes may be made semi-automatic or fully automatic so that the same conditions exist throughout the process of making a long joint, regardless of the state of mind of the operator. Skill, however, is required to make the original adjustments for the automatic machines.

Let us now turn briefly to the consideration of some of the factors affecting the quality of the welded joint and, inasmuch as you are mostly interested in the welding of steel, this discussion will be largely confined to that variety of steel most used in your business.

The physical properties of a piece of steel depend largely upon its chemical composition and upon its heat history. All metal is crystalline in its structure. When steel cools from the molten state, it crystallizes and these crystals combine in groups to form what are commonly known as grains of varying shapes and sizes, and the size of these grains is largely a question of their heat history, that is, the temperature to which the metal has been raised, the time it has been held there, the rate of cooling, etc. Under the conditions of cooling in the ordinary arc weld, the grains are very coarse and, although the metal may have ample tensile strength, it is almost universally brittle. By proper heat treatment, such metal may be refined as to its grain size with an accompanying change of properties, particularly as to its ductility.

It just happens that in the making of arc welds in heavy plates, it is practically necessary to deposit the metal in layers, in which case each layer puts the layer below it through an ideal heat treatment as far as grain refining is concerned. This is particularly true in heavy plate welding where large currents are used and where sufficient heat is thereby transmitted to the underlying layer to carry it through this refining process. It is obvious, however, that the depth of penetration of the refining heat is limited and, therefore, that it is necessary to restrict the thickness of the layers to that point.

In the gas welding, however, the layer process of deposition would involve a very large waste of heat and gas and would be very expensive. Moreover, the temperature of the superimposed refining layer is not as high as in the case of the arc. It is thus not possible with gas welding to obtain as fine a grain structure or as ductile a weld as in the case of the best covered electrode arc welds. The weld metal is, however, just as pure and free from oxides or nitrides or slag inclusions. It has also just as high a tensile strength, in fact it is equal in every respect except as to a slightly lower ductility. Moreover, as, compared with bare arc welding, it is distinctly superior in that it is not only free from oxides and nitrides, but is also more ductile, lying somewhere between the bare electrode weld and the best covered electrode welds with layer deposit.

This brings us to a very important question on which the doctors disagree. When is the slightly lower ductility of one of these welds without grain refinement any serious handicap to the safety of the resulting structure, assuming of course, that the tensile strength of the joint is equally high in both cases, and this is the fact.

I am not going to answer this question for you,

as it is one which depends upon a great many factors. I will state, however, as my personal opinion that there are very few structures in which this lower ductility has any influence on their satisfactory service.

In recognition of these facts, the last publication of the proposed Boiler Code Specifications advised that in the case of Grade B welding 20 per cent elongation under bend tests be required for arc welding and only 15 per cent for gas welding. This should be considered in no sense a reflection upon gas welding, as it is entirely possible for the 15 per cent ductility gas weld to be superior to the 20 per cent ductility electric weld.

Just one more point in connection with this ductility question. In most constructions under consideration, there are openings around which stresses are concentrated. If the material around these openings has a low yield point, the resulting yield will tend to equalize the stress, whereas in the less ductile material it is more apt to start a fatigue failure.

Thus far, I have spoken of the quality of welded joints in terms of the chemical composition and the heat history of the metal on the assumption that the metal was homogeneous and uninterrupted by blow holes or slag pockets of any kind. It is a fact, however, that in the case of arc welding with either bare or covered electrodes, great care is necessary to avoid gas or slag pockets or the finer type of porosity. In other words, you may have a highly refined grain of the proper composition with all the desired physical properties, but if there is present a single slag pocket or gas pocket beyond a certain size, there is great danger of fatigue failure starting at this point.

You have doubtless been told that welds are being made which are superior in every respect to the parent metal, and this is in general true, but I wish to assure you that that is not the whole story and that it is not a simple matter to produce a perfectly homogeneous non-porous weld metal. If the pores are very small and uniformly distributed, they will probably not affect the satisfactory functioning of the resulting joint in any way, but the larger pockets are distinctly dangerous and these do occur occasionally in the best-regulated families.

It is on this account that the X-ray test is included in the Boiler Code, since it is the only method of detecting this type of defect.

I have spoken of the danger of fatigue failure starting at one of these gas pockets and wish at this point to give perhaps a little clearer picture of what actually happens. Doubtless most of you have read Professor Moore's report on breathing tests carried out on some ten or a dozen cylindrical shells made by various processes, most of them welded. Hydrostatic pressure was applied repeatedly such as to produce a stress 50 per cent above the allowable working stress. The bare electrode welded drum failed at about 6000 applications of this stress, which was below the yield point of the metal. The failure occurred through a slag pocket in the weld, that is a concentration of stress at this point was sufficient to initiate a crack which gradually grew until it included the whole shell plate thickness. Several other welded drums failed in the base metal around a point at which a gage tap was threaded in. These failures occurred at about 250,000 applications. Some of these were made without any openings in the drum wall and stood up for 2,000,000 applications without failure.

In another case, a manganese steel drum of riveted construction had tack welds on the outside to support strain gage connections and twice this drum failed under fatigue, the failure starting at the point of the tack weld, due merely to stress set up by the shrinkage of the weld metal.

It is on this account that the Boiler Code Committee is so insistent upon X-ray tests to prove the absence of slag or gas pockets in the welded joints. I don't suppose that even boiler makers or boiler users know how many times the pressure in a boiler is raised up to its limit and down again during its life. It certainly does not have 50 per cent more than this pressure applied for 200,000 times. But there must be a factor of safety in the application of any such test knowledge as I have recited, particularly when failure involves so much danger to life and property.

In other words, the Boiler Code Committee is placed in the position where it must play safe. I want to say that if I were a boiler manufacturer and knew all that I know now about the welding game, I would not only not oppose any of the restrictions in the present proposed specifications for welding boiler drums, but I would gladly accept them. In fact, I would not put out a boiler drum which I had not satisfied myself was free from those faults which do occur, as we say, in the best-regulated families.

Welding is a fussy, old maid's job and the reason why its development has been held back for twenty years or more is merely due to the fact that it has been in the hands of those who did not comprehend fully the nature of the problem. I grant you that much satisfactory welding has been done in years past but mostly in structures not of the critical variety now under consideration, that is, in structures where the demands made upon the weld were not severe.

Referring again for a moment to the X-ray examination, its greatest value is in aiding the manufacturer to develop a technique which will produce uniformly practically perfect welds. Without some such aid I doubt if such a technique could be developed.

Gamma rays were referred to this morning. Unfortunately, I cannot give you very exact information as to the cost of gamma radiographing, but I am convinced that the definition of the radiograph is not nearly as clear as in the case of the X-ray. It is, however, possible to apply this to thicker walled drums although the time required is very considerable.

The source of gamma rays is either radium or

radium emanations, the former lasting forever and the latter only for a few days. A gram of radium costs about $75,000 and for very heavy walled vessels it might take an hour or more to get a single picture. If you could keep the radium busy twenty-four hours a day, the cost would be relatively low but for infrequent use it would be prohibitive.

Turning now to the question of the qualification of welders which the Boiler Code requires every six months, it is very difficult to transmit a proper conception of the danger of poor welding. Even with an automatic machine the adjustments must be properly made and the machine must be watched throughout the welding of a seam or beam.

In this connection, I should like to mention a case brought very recently to my attention. A storage tank 40 feet in diameter and 40 feet high, containing an expensive vegetable oil, had its bottom welded, the plates overlapped and fillet welds were made on the upper side. The bottom, which rested on the earth, failed with a loss of $25,000 worth of oil, and this failure will cost someone eventually at least $50,000.

The welding work was done by a supposedly responsible welding contractor with a large shop and a large number of welders employed. The actual strength of the welds was from one-quarter to one-third the normal full fillet weld. To anyone who knows what good welding is, this particular job was unbelievably rotten. In some cases, there was no bond at all between the deposited metal and the plate. This work was done within the past six months and looked perfectly good on the outside to any casual inspector.

It is very difficult, even with the greatest possible care and the most perfect development of procedure, with the best materials and machines available, to produce consistently, day in and day out, joints that are free from slag pockets or gas pockets or porocity to a considerable extent. It therefore behooves us to preserve every possible precaution, not only in the original qualification of a welder and in keeping him up to his job, but also in the design of the joints, the selection of the electrodes, both as to size and quality, the employment of the proper current in the case of arc welding, and the layout of the procedure or technique.

Referring again to the matter of electrodes, there are hundreds of varieties of coated and covered electrodes, most of which have been developed by the cut and try process and often patented by men who know very little about the scientific aspects of the problem. Some of them meet the desired specifications in part but very few of them meet all of the specifications satisfactorily. Moreover, the best of them may produce very unsatisfactory results in the hands of an unskilled welder.

Undoubtedly much satisfactory welding has been done for many years past but mostly in places or in structures which are not of the critical variety with which we are here concerned.

The most important message that I wish to leave with you is that the welding problem is not a simple mechanical problem like that of riveting, but that it requires for its solution a thorough knowledge of metallurgy, physics and of chemistry. You can get about so far by the cut and try process but ultimately it is a job for the highest type of scientific engineer. In this connection, I am going to beg your indulgence while I ride my hobby for a few minutes.

A shamefully small percentage of engineers, even in high standing, are competent to solve intelligent-

(Continued on page 24)

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Tangential Firing of Gaseous and Liquid Fuels

(Continued from page 15)

tion of natural gas varies over a wide range. The heat content will be from 750 to 1125 B.t.u. per cu. ft., depending on the percentages of nitrogen, oxygen and carbon monoxide present. When compared with blast furnace gas, it is very rich because of the hydro-carbon content. The speed of ignition is greater and the resulting furnace temperature higher. Because the gas is rich, the mixing with the air for combustion is not so difficult. However, if turbulence is lacking, long flaming and stratification are sure to occur. By using the tangential method of firing, we not only have turbulence at the burner but continue the mixing of the gas and air until the combustion process is completed. With this condition existing, it is possible to operate with a very low percentage of excess air in the furnace.

While none of the installations referred to have burned natural gas, it is not difficult to conceive that its use, in a tangentially fired furnace, is simply a question of burner design. With this method of firing, stability of ignition is assured over an extremely wide range of ratings. The use of a water-cooled type of furnace makes it possible to meet variations in steam demand instantly. The application of automatic control equipment will serve to maintain uniform steam pressure at the turbine throttle with a minimum of effort on the part of the operating personnel.

Furnaces of the types described were originally designed for burning pulverized coal. The results obtained indicated that "tangential firing" was fundamentally correct. The applications to blast-furnace-gas-fired installations gave results that absolutely proved the soundness of tangential firing. The widely differing characteristics of these two fuels serve to emphasize the universal adaptability of tangential firing to pulverized, gaseous and liquid fuels.

New Steam Traps for High Pressures and Large Discharge

The author discusses the design, construction and operation of steam traps, especially two new designs recently developed abroad. The proper functioning of steam traps is of particular importance in industrial plants where the traps are used in connection with various kinds of heating apparatus. For this reason most of the discussion revolves around such applications.

By C. H. S. TUPHOLME,
LONDON

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THE developments of recent years in steam generation practice have also involved changes in the demands made on auxiliary equipment and apparatus, including steam traps. Working with high pressure steam requires traps of special design and construction, since it becomes more and more difficult to insure faultless operation of the closing member as the steam pressure increases. In addition to that, the heating apparatus now used is generally larger and capable of higher output than formerly, so that larger quantities of condensate have to be handled, and the individual discharge capacity of the traps must be increased. Another reason for increasing the size of the traps is to reduce the cost of attendance by connecting several heating apparatus to a single trap.

Steam traps generally operate with little attendance, and must therefore be designed as simply as possible in order to insure reliability of working under all conditions. In power stations, where such apparatus is used only for draining steam lines, reliable working is of less importance than in cases where the traps are connected to heating apparatus such as is found in chemical works, and foodstuffs factories, since in such cases the results depend directly upon the efficient operation of the apparatus. In plants of the type mentioned the rate of heat exchange is a deciding factor, and this will be decreased, not only if the steam trap lets off too little water and condensate accordingly collects in the heating apparatus, but also if steam blows through.

Traps for use on high pressure steam piping are of compact construction in order that they may withstand the high pressures to which they are submitted (see Fig. 1). They are generally constructed with ball valves and open or bucket floats. The bucket float does not cause any trouble, even if it leaks slightly in service. A non-return valve is fitted before the trap to prevent the condensate in the trap being evaporated by the superheated steam in the pipe.

The economical range of pressure within which a trap can work, is determined on the one hand by the cross sectional area of the valve opening, and on the other hand by the weight of the float. The latter determines the highest pressure at which the float can still just open the valve. The valve opens also at lower pressures, but the rate of discharge for the same valve opening decreases very quickly in consequence of the lower pressure. It is therefore preferable to make the cross sectional area of the valve opening and seat to suit the working pressure exactly.

The trap for super high-pressure steam, as illustrated in Fig. 1, is made in various sizes and for pressures up to 910 lb. per sq. in. The discharge capacity ranges from 2200 to 7000 lb. per hr. depending on the size of the trap and the working pressure.

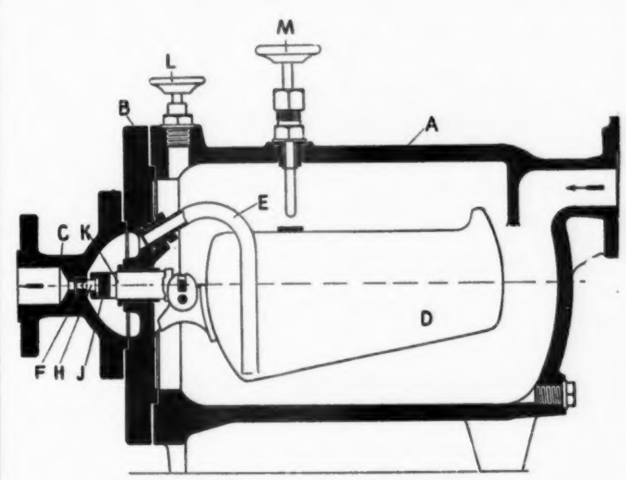
When the float D is filled with condensate it tips to the bottom and draws the piston K with it, so that the valve H opens. The condensate is then forced out through the pipe E by the steam pressure, after which the float rises again and closes the outlet. By screwing down the spindle M, the float D can be pressed down and the valve H opened to blow through the seat F. Air is let off from the trap through the valve L.

In order to shorten the time required for overhauling the trap, all moving parts are fitted to the cover B, so that the float and valve can be withdrawn when the cover is removed. For replacing the valve and its seat, it is sufficient to remove the piece C.

Since the size of the outlet orifice will be comparatively small with the high steam pressures, the velocity of the condensate when being discharged through it is very high, causing rapid wear of the closing members, so that these have to be constructed of a special metal, V2A steel being now generally used.

The position of the steam traps with regard to

distance and level in relation to the heating surface, and also the run of piping before and after the trap, are matters which must receive careful attention. The effectiveness of the trap will, for example, be greatly influenced by the diameter of the piping leading the water away from it. Since the condensation enters the trap at a saturation temperature corresponding to the pressure of the steam, there will afterward be a certain amount of re-evaporation, more or less great, depending on the pressure at which it is discharged, until water and steam have reached the saturation temperature corresponding to the pressure in the outlet pipe. In this way the volume of the condensate at the outlet from the trap may be increased quite considerably, and even if a far higher rate of flow can be allowed for this mixture of steam and water



A	Steam trap	F	Valve seat
B	Cover	H	Ball valve
C	Discharge branch	J	Cap nut
D	Float	K	Piston
E	Siphon	L	Valve
		M	Spindle

Fig. 1—Steam trap with ball valve and open float, for pressures up to 900 lb. per sq. in.

than for water alone, the drain pipes must still be chosen amply large in order to prevent too great an increase in pressure behind the steam trap.

In chemical and dyeing plants, paper mills and similar works the individual boiling vessels and heating apparatus now used are much larger and of greater output than formerly; consequently, the steam traps must be of much larger capacity. Also, in these works, much of the heating apparatus is in service simultaneously. If traps of the usual type are used to lead away the condensate, at least two traps would have to be fitted to each heating apparatus because of the size of the latter and the great quantity of condensate to be discharged. The cost of attendance is thus much increased, since with the usual valves there is very great wear on the closing members in consequence of the high velocity of discharge, and these parts have to be renewed frequently in each trap.

For this reason a steam trap has recently been designed and is now on the market which has not only a high capacity of about 22,000 to 38,000 lb. per hour at 70 to 140 lb. per sq. in., so that it can remove the condensate from a large number of apparatus, but is at the same time much more reliable in service, since the closing members are only operated indirectly by the float, and the cross sectional area of the discharge orifice can therefore be very large. In this manner the chief cause of breakdowns, i.e., excessive wear in the closing members, is claimed to be entirely eliminated.

The effective capacity of heating apparatus depends to a large extent on the steam trap fitted after it, so that also the efficiency of the service depends on the trap. If the trap cannot let off sufficient water, the heating apparatus will fill up with it, thus reducing the heating surface and lowering the temperature. The heating effect is consequently diminished.

This will be the case particularly in a boiling process where the material treated is at first cold; much steam will be condensed exactly when the full effect of the heating surface is required. The further the heating steam can freely penetrate to the end of the heating surface the greater will be the heating effect. At the same time the temperature of the condensate flowing away will increase, and this will give some indication of the conditions under which the apparatus is working.

The nearer the boundary between water and steam is pushed to the end of the heating surface, the nearer will the temperature of the condensate approach the temperature of saturation of the steam. Therefore, if the condensate is led off quickly enough, and if the steam reaches the end of the heating surface, the maximum heating capacity of the heating surface will be obtained. To endeavor to get a greater transfer of heat by increasing the speed of the steam would only have a conditional success.

The steam which is condensing has already so much internal conductivity that the heat transmission in the heating apparatus can hardly be improved by greater steam velocities. If, in some arrangements, this does appear to increase the heating effect, it is probably to be attributed to condensate being blown away and to more effective removal of gas and air. The higher speed of the steam, however, causes at the same time a greater fall in pressure, depending upon the type of heating device, and this in turn will cause the steam temperature to fall so that the effective action of the heating surfaces diminishes very quickly. In addition to this, an addition in the steam velocity can only be obtained by direct blowing-off of steam, which is uneconomical. From this it will be seen that a steam trap must always be designed to suit the heating surfaces of the apparatus to which it is connected so that such apparatus can work continuously at maximum capacity. The trap must therefore be capable of leading away the condensate at such a rate that the boundary between condensate and steam always remains at the end of the heating surface.

Fig. 2 shows longitudinal and cross sections

through this high capacity steam trap. Since the trap has to remove large quantities of water, the float is used only to put the valve gear in and out of action. When the steam trap fills with water, the float A rises and reverses the lever B. This lever moves a slide valve in the casing C, thus connecting the piping D with the piping E. The condensate which is under steam pressure, can then pass through the piping E into the space over the double piston F. Although the lower piston stands under the same steam pressure, the double piston F is forced down into the position shown in the drawing, because of the larger surface of the upper piston. The lower piston consequently opens the outlet H and connects it with the pipe G, so that the condensate, in consequence of the excess pressure, can pass out through the pipe G and the space between the two pistons. When the float sinks to its lowest position, it reverses the lever B into the position shown in dotted lines, whereby the slide valve closes the piping D and connects the pipe E to the outlet H. The water under pressure can then flow away freely out of the upper steam space, so that the pressure on the upper piston decreases and the double piston F is pushed up in consequence of the steam pressure on the lower piston. The lower piston consequently shuts off the pipe G and prevents any further escape of condensate. The valve I serves to let off air.

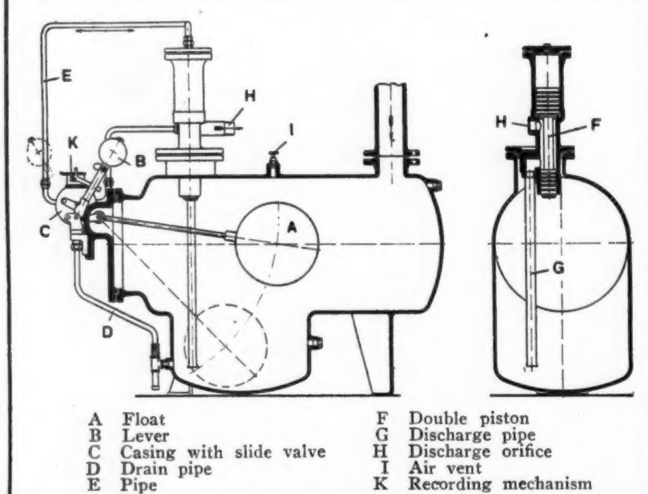


Fig. 2—Section through a recording steam trap for discharging 22,000 to 37,500 gal. per hr. at working pressures of 70 to 140 lb. per sq. in.

By arranging the double piston F as a closing member only indirectly operated by the float, as great a force as is desired is available for opening that member. Consequently, in spite of the larger quantity of water discharged, the cross sectional area of the outlet can be made of such a size that the velocity of discharge is low. In consequence of the low discharge velocities, the wear on the members controlling the outlet is very slight. The valve controlled by the float has only to pass a small quantity of water each time, just as much as is necessary to reverse the position of the double piston. In this way the principal source of trouble is eliminated.

A counting mechanism K can also be fitted to the new trap. This is operated each time the lever B is moved into the position shown in dotted lines. In works of the type mentioned earlier in the article, it is often desirable to control the service by measuring the quantity of steam condensed. By the adoption of the valve gear referred to, the outlet is opened and closed each time exactly at the same position of the float and the condensate is expelled quickly. It is therefore possible to obtain an accurate measurement of the quantity discharged by simply counting the number of operations.

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Address to the American Boiler Manufacturers Association

(Continued from page 21)

ly a problem involving anything approaching real scientific research work or analysis. This is largely the fault of our educational system. In our engineering schools they are rushed through the fundamental sciences. They wish to learn practical things, the technique of their profession. They are taught how to solve certain types of problems, always with more or less crude approximations. In any particular case, the solution is valid only for a comparatively narrow range of practice or application, and when applied outside of that range they give seriously erroneous results. Then their employers say, "You are too theoretical," when as a matter of fact they are not theoretical at all; they are just glorified mechanics applying formulae, the development of which they do not understand. The trouble with most of our teaching is that it cultivates the habit of listening, remembering and repeating, and doing a job in just the way they are taught to do it, rather than starting at the bottom and thinking out each problem in the light of the particular conditions surrounding it.

It is very difficult to cultivate this habit of thinking for oneself, particularly when the other habit has been drilled into one from the kindergarten up.

The thing that has held back the development of the art of welding for all these years has been the fact that its development has been for the most part in the hands of so-called practical men, to whom welding is just welding, who do not understand the operation of the many factors or variables involved in the problem, who cannot understand the connection between the cause and the effect, and who have neither the habit of analysis nor the foundation upon which to build it.

Hydrogen Ion Determinations in the Steam Plant

By C. E. JOOS
Chemical Engineer, Cochrane Corporation, Philadelphia

The author discusses the factor of hydrogen ion concentration, commonly referred to as pH value, explains the reactions involved and their significance. The pH value is a measure of the active acidity or alkalinity of a solution and can, therefore, be used to predict the tendency toward corrosion or embrittlement. Instruments are available which make the determination of pH value a comparatively simple matter. The author describes the two methods on which such instruments are based, namely, the potentiometric method and the colorimetric method. He then discusses the significance of pH value in connection with boiler waters of various characteristics and when using various methods of feedwater treatment.

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IN the chemical industries, wherever the character of the product depends upon the degree of acidity or alkalinity within narrow limits, hydrogen ion determinations have proved of inestimable value and many processes are guided by such determinations to the exclusion of the older method of titration with acid or alkali. The use of the hydrogen ion concentration or pH value in the steam power plant is rather new, but is rapidly finding more extended use, and frequently pH determinations have explained the causes of metal corrosion otherwise not obvious from determinations of acidity or alkalinity by titration methods.

Briefly, the pH value indicates with a high degree of accuracy the degree of active acidity or alkalinity as contrasted with total acidity or alkalinity determined by titration methods. For an explanation of the meaning of the pH value we must turn to the causes of acidity and alkalinity. Pure distilled water is composed of molecules expressed as H_2O or HOH and also of hydrogen and hydroxyl ions expressed as H^+ and OH^-, respectively. Now, the ions are formed as a result of the splitting up of the molecules, and molecules will form as the result of the combination of ions, as represented by the formula.

$$H_2O = H^+ + OH^-$$

The processes of splitting and recombination continue but reach an equilibrium where splitting and recombination are exactly equal, so that the total number of ions and molecules remain constant. According to the law of mass action, the rate of combination is proportional to the product of the numbers of the respective combining ions present. Therefore in the case of pure distilled water we may write the following expression:

$$\frac{H^+ \times OH^-}{HOH} = k$$

wherein k is a constant expressing the degree of ionization at any given temperature. Since water is only slightly ionized, we can without appreciable error consider the non-ionized portion as unity, in which case the expression becomes—

$$H^+ \times OH = k$$

By experimentation k has been determined to have the value of 10^{-14}.

Active acidity or active alkalinity is proportional to the number of hydrogen ions or of hydroxyl ions, respectively, in solution. Pure water is neutral, consequently the number of H ions must exactly equal the number of OH ions, so that the concentration of H ions is equal to the square root of 10^{-4}, or 10^{-2}.

Since the product of the H ions and the OH ions equals a constant, it follows that if the H ions or active acidity increases, the OH ions must decrease, and conversely if the OH ions or active alkalinity increases the H ions must decrease. Consequently any degree of active acidity or active alkalinity may be expressed by the hydrogen or by the hydroxyl ion concentration alone, and it is not necessary to designate active alkalinity by hydroxyl concentration and active acidity by hydrogen ion concentration, but the degree of hydrogen ion concentration can be used to express either active acidity or active alkalinity. The designation pH which has come into general use may be defined as—

$$pH = \log \frac{1}{H^+}$$

It is not necessary to have a knowledge of chem-

istry to interpret hydrogen ion values, but only to remember that a neutral aqueous solution has a pH value of 7.0, that an acid solution has a pH value less than 7.0 and that an alkaline solution has a pH value greater than 7.0, also that since the pH values are logarithmic functions, a solution having a pH of 5.0 is ten times as acid as one with a pH value of 6.0, while a pH value of 9.0 represents ten times as much active alkalinity as does a pH value of 8.0.

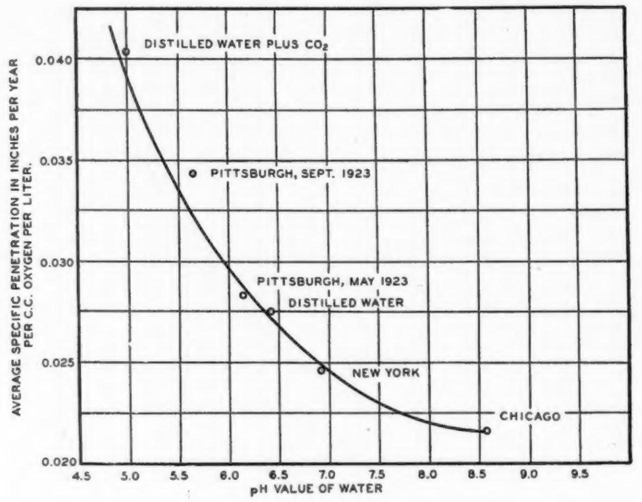

Fig. 1—Relative Corrosiveness of Several Waters. Reproduced from "Corrosion" by F. N. Speeler—page 340.

Since the pH value is a measure of the active acidity or alkalinity of a solution, it can be used to predict the tendency towards corrosion, whereas the total acidity or alkalinity does not measure the activity or aggressiveness of a solution. For example, concentrated sulphuric acid is only very slightly ionized and can therefore be shipped in steel tank cars, whereas dilute sulphuric acid, having a strength of only 5 or 10 per cent is highly ionized and very destructive to steel. This is a typical example showing the difference between pH value and the total acidity. In the same way some acids are considered stronger than others because the ionization of their solutions is greater. Thus if two one-tenth normal solutions contain the same total acidity, one due to acetic acid and the second due to hydrochloric acid, as measured by titration with an alkali, the pH value of the hydrochloric acid solution will be 1.04, whereas that of the acetic acid will be 2.89, which means that the hydrochloric acid will be approximately 70 times (2.89 — 1.04 = log 70) as active as the acetic, although the total acidity is the same. Because of this difference in ionization, different acids and alkalies are designated as weak or strong. As applied to corrosion, for example, pH value measures the intensity of the corrosive action while total acidity measures the amount of corrosion that will occur before the acid is exhausted.

As an example for alkalies, three-tenth normal solutions containing sodium bi-carbonate, sodium carbonate and sodium hydroxide, all of the same total alkalinity will have values of the order of 8.4, 11.6 and 13.0 respectively.

The significance of pH values in steam plants appears in the adjustment of alkalinities for the prevention of corrosion or in obtaining maximum precipitation from lime soda softeners.

If we now consider a water in terms of its activity or pH value, we can readily see why some waters are more corrosive than others, even though they may be more alkaline as measured by titration. Fig. 1 illustrates the relation between pH values and corrosiveness of city water supplies. The curve is reduced to corrosion per cc. of oxygen per liter and so is a direct indication of the part that the pH value plays in corrosion. Fig. 2 gives additional evidence of the significance of pH values.

In steam plants we are chiefly interested in the make-up water, both in the raw and treated states, and in the condensate return, which also forms a part of the total feedwater. Therefore, we should take into consideration the significance of pH values in the following water supplies.

1. Raw water
2. Filtered or treated water
3. Condensate
4. Feedwater leaving heater or deaerating heater
5. Concentrated boiler water
6. Condensed steam

A number of instruments have been developed and placed on the market which make the determination of hydrogen ion concentration easy and simple and which do not require technical knowledge concerning the derivation of pH values. The instruments are based on two different methods.

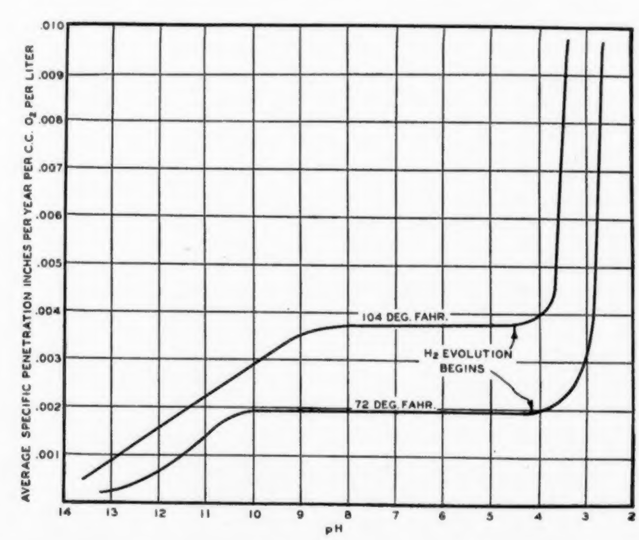

Fig. 2—Effect of Hydrogen Ion Concentration on Corrosion of Steel. Reproduced from article by W. G. Whitman, Russell & Altieri, pages 665-670, 1924, "Industrial and Engineering Chemistry."

First, the potentiometric method, which is direct and the most accurate and is used where a continuous record of pH is desired.

Second, the colorimetric method, which while not

so accurate as the potentiometric method, has found wide use where a high degree of accuracy is not required, as in the steam plant for example. The advantages of this method lie in the simplicity of the apparatus and the ease with which the determination may be made.

The potentiometric method measures the voltage developed by the hydrogen ions present in the solution examined, and since there is a definite relation between this voltage and the concentration of hydrogen ions, it is an indication of the pH value. A hydrogen electrode is used as the negative pole, a calomel electrode as the positive pole, the voltage developed being balanced against a standard cell of known potential by means of the potentiometer. The hydrogen electrode is obtained by passing gaseous hydrogen over a piece of platinum covered with finely divided platinum.

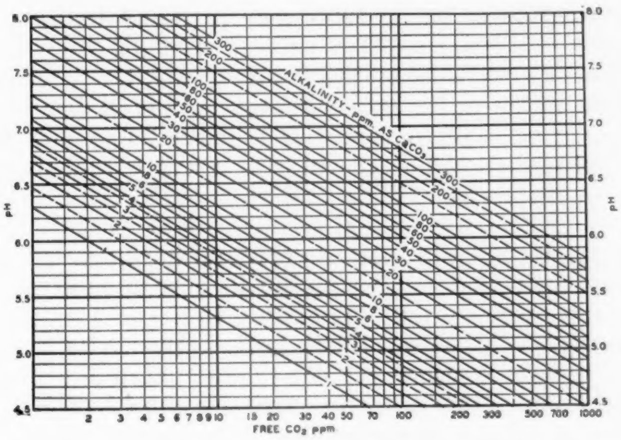

Fig. 3—Graphic relation of pH, alkalinity and free CO_2.

The colorimetric method depends upon the action of certain dyes or indicators in changing colors in solutions of certain pH values. To cover the full range of pH values a number of different indicators are used. In operation it is only necessary to take a small sample of the liquid to be tested, add to it a measured quantity of the indicator and compare the resultant colors with fixed standards corresponding to known pH values.

The pH value of raw water supplies can be considered as due to the carbonate hardness, which is made up of an alkali and free CO_2, an acid. The pH value depends upon the amount of each constituent present. There is a certain definite relation between the carbonate hardness and the free CO_2 which determines the pH value and which can be expressed according to the following approximate formula:

$$pH = \text{Log} \frac{CaCO_3 \times 2}{CO_2} \times 1{,}000{,}000$$

wherein the carbonate hardness is expressed in parts per million as calcium carbonate and the free CO_2 is expressed in parts per million. Fig. 3 illustrates these relationships in graphic form. The pH value can be determined from analyses where the total carbonate hardness and the free CO_2 are given, or conversely if the pH value and one of other factors are given, the third can be computed.

The pH value of the raw water is not only significant from the standpoint of corrosion of the cold raw water lines, but particularly so where exchange or zeolite softeners are used or where coagulation is necessary. The maximum efficiency in the use of a coagulant is attained at a certain pH value found by practice or experiment. In the case of highly colored soft waters prevalent in many districts, as in certain sections of New Jersey, Wisconsin, New York and Minnesota, the pH value for the maximum precipitation by alum is usually in the neighborhood of 5.0 to 6.0. This represents a water of active acidity and for the protection of pipe lines, etc., it is generally recognized that this pH should be increased by the addition of alkali to the filtered water in the form of lime or caustic soda. In one plant with which the writer is familiar, the pH value of the filtered water is maintained at 5.2. As this is so low as to cause corrosion of pipe lines, it is bolstered up by the addition of caustic soda, to between 7 and 8. At higher temperatures this value would have to be increased because of the increased activity of dissolved oxygen.

In some waters the desirable or optimum pH value may lie considerably below the initial pH of the raw water, so that the reduction in pH value by means of the coagulant will call for larger doses than necessary for formation of the floc, thus placing a greater load upon the sedimentation basin. In such cases the pH value is lowered by the introduction of sulphuric acid to a point such that with a small dose of coagulant the optimum pH is reached. By coagulation at the optimum pH, advantage is taken of the most economical alum dose; therefore disregard of this optimum pH is apt to result in an extravagant use of alum.

Some waters may coagulate best at their original pH value or at a value somewhat higher, in which event the pH must be bolstered up by the use of an alkali such as lime or caustic soda.

In the clarification of turbid waters, the optimum pH value should be determined experimentally by conducting jar tests. These tests are made by taking 500 or 1000 cc. of raw water and adding increasing amounts of coagulant in steps of ½ grain or less. The samples are stirred, allowed to settle and observations made as to the best sample as to clarity after filtering through cotton or a laboratory filter. Observations are best made by using standard color tubes as prescribed by the American Public Health Association, otherwise the results may be misleading. After the optimum pH has been established, steps should be taken to reduce the coagulant, maintaining the optimum pH by the addition of acid. In the small plant the resulting savings may not justify the additional trouble of using sulphuric acid.

The importance of clarification of colored waters for boiler feed purposes was demonstrated to the writer in a textile plant equipped with an elaborate filtration and zeolite softening system designed to prepare a mildly colored water for the process and for boiler feeding where, as a result of improper

coagulation, the removal of organic matter was only partial, causing a high concentration of organic matter in the boiler, which resulted in foaming. A laboratory determination of the optimum pH and the maintenance of this pH in practice resulted in the practically complete removal of the coloring matter and in the elimination of foaming, while the purified water was made better for process purposes. In this instance the pH of the filtered water was between 5.0 and 6.0, and in order to protect pipe lines from corrosion, alkali was added to bring the pH to approximately 7.0.

In certain districts, as around Pittsburgh, the pH values of river water are very low, such waters being very destructive to pipe lines, due in part to contamination by mineral acid. The low pH is corrected by the addition of lime. During the past summer, the drought made certain waters of the

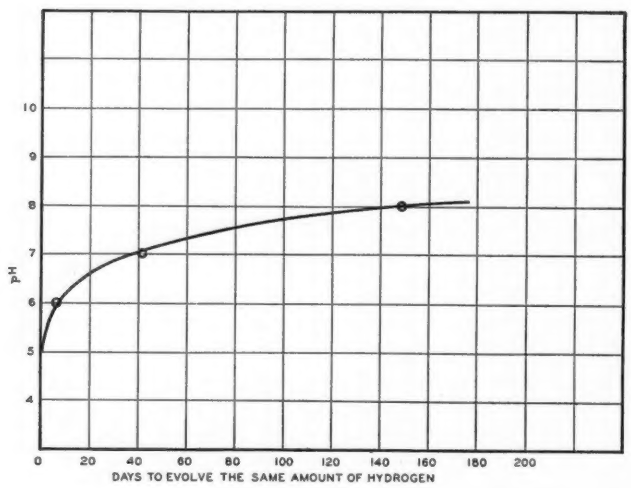

Fig. 4—Effect of pH on Hydrogen Gas Evolution. (Corrosion in absence of oxygen.) Reproduced from article by J. W. Shipley and I. R. McHaffie, pages 121-124, 1924, "Canadian Chemistry and Metallurgy."

Pittsburgh district very acid, necessitating the introduction of large quantities of lime.

In the average steam plant, however, the raw water rarely has so low a pH value that it is destructive to the cold water piping, although it is well known that the life of ordinary piping varies with the district, as might be inferred from Fig. 1.

Where particularly soft water prevails, as in New England, cast iron and steel equipment has been known to have a life shorter than expected due to corrosion accelerated by a low pH value. In these districts the pH value of many waters is below the neutral point of 7.0 and there have been cases of graphitization of cast iron which are not ordinarily found and so cannot be considered as a fault of the metal. Similarly, zeolite softened water which has been given an after treatment of sulphuric acid has a very low pH value and consequently is destructive to heating equipment. The engineer should therefore determine the pH of the raw water when seeking the reason for corrosion of cold water lines.

As an example, a plant using a water of the following characteristics experienced corrosion of the cold and hot water lines:

	Parts per Million
Free CO_2	20
Alkalinity	4
Total Hardness	15
pH	5.6

Deaeration did not remedy altogether the corrosion of the water system which was corrected only by the addition of alkali to increase the pH value.

Filtered or Treated Water

Because of the several methods used in the treatment of the feedwater, such as the hot process lime-soda system, the zeolite system, as well as evaporators, boiler feedwater is likely to have a very wide range of pH values. The pH value and the oxygen concentration are particularly important in boiler feedwater because of the higher temperatures. If we consider a plant using 100 per cent make-up, the pH value of a water treated in a zeolite softener will depend upon the initial character of the raw water, its method of preparation, etc., and inasmuch as the original hardness is simply converted by the zeolite to corresponding sodium salts, without any change in the acid radicals, the pH value is not likely to be high. Where acid treatment is resorted to, for the reduction of sodium carbonate, the pH value will be considerably reduced. Because of the liberation of free CO_2 and the decrease in the carbonate content a prediction as to what pH can be expected can easily be made from Fig. 3.

In the case of evaporators, a pH value may be obtained even lower than with a zeolite water softener, because here the distillate or make-up water would contain no carbonate radical, yet at the same time all of the free CO_2 liberated within the evaporator passes over with the steam and redissolves in the condensate. Therefore, evaporated make-up, in the absence of priming from evaporators, is likely to be distinctly on the acid side. The free CO_2 can, however, be eliminated by deaeration.

With the precipitation type of softener such as the lime-soda ash softener, complete control can be had over the pH values because the precipitation of the carbonates is under control, as well as the removal of CO_2. In a properly operated lime and soda softener, the CO_2 can be reduced to absolute zero, whereas the carbonate content can be increased to any desirable range within practical limits. Moreover, the excess of treating agent, which is always necessary, can be maintained in either the bi-carbonate, carbonate or caustic condition.

As an illustration of the meaning of pH values in a feedwater system using 100 per cent of zeolite softened make-up water, the following table is taken from published data relating to the operation of the Beacon Street Heating Plant of the Detroit Edison Company:

	P.P.M. pH Value— Analytical Results
Raw water	7.6
After Zeolite	8.1
After acid feed	6.2
After deaerator	8.6
After adding recirculated blow-off	9.8
Boiler water	11.3
Steam	6.0

The introduction of acid reduces the pH value as might be expected, while the elimination of CO_2 within the deaerating heater brings about a very marked increase.

By way of contrast, the following series of tests of treated water from a hot process lime-soda softener are presented, the Pht. and M.O. values being taken on a 100 cc. sample titrated with 20th normal acid, with the corresponding pH values for comparison.

Treated Water

PHT.	M.O.	pH
.50	1.5	8.9
.70	1.7	9.15
.90	1.85	9.2
1.15	2.0	9.25
1.17	2.2	9.7

With this type of softener the pH value is under definite control because of the ease with which the chemicals used for softening may be regulated, and, a range in pH values from 8.9 to 9.7 is possible with very little change in total alkalinity, as indicated by the M.O. indicator.

A suitable pH value of the treated water is particularly important for preventing corrosion in feedwater heaters, feed lines and steel tube economizers. While in most cases corrosion can be prevented even in the most sensitive equipment, such as steel tube economizers, by reducing the oxygen content to zero, it does not follow that this alone is always sufficient, a fact which has been appreciated by deaerating heater manufacturers for years. Refusal to guarantee protection against corrosion without control of the pH value is justifiable because in some cases corrosion will proceed even though water is entirely free of oxygen content. Fig. 4 shows the rate of corrosion at different pH values in the absence of oxygen.

Plants using distilled water make-up have found it desirable to add alkali in order to bolster up the pH value to prevent attack on the metal.

Recognizing the importance of pH control of feedwater, a number of methods have been used in order to increase the pH value to the point where corrosion is prevented. Where the water is very low in carbonates, the addition of caustic soda to a zeolite-softened water has proven satisfactory, although it is quite obvious that any introduction of alkali will necessarily tend to increase the boiler alkalinity and is apt to throw out of balance the sulphate-to-carbonate ratio required for the prevention of embrittlement. Better than the introduction of caustic, a number of plants have returned a portion of the boiler blow-off water to the feedwater heater storage space in order to protect the heater, the feed lines and the economizers from corrosion. This method has the advantage that an appreciable amount of caustic can be introduced into the feedwater to increase the alkalinity and pH value without necessarily increasing the boiler alkalinity. However, it must be remembered that the amount of water recirculated is independent of that necessary for blow-down and that heat is transferred directly from the boiler to the feedwater, thus sacrificing the mechanical energy that could have been produced from bled steam used to heat feedwater and secondly the water must be pumped back to the boiler, adding an appreciable pumping charge, particularly in high pressure plants. However, where the softening system does not permit of control of the pH values, such losses in economy must be sacrificed in order to protect the metal against corrosion.

The effect of recirculating boiler water is shown in Fig. 5 relating to an integral steel tube economizer, which, due to the high oxygen content of the feedwater suffered corrosion. In order to observe the effect of recirculating concentrated boiler water, a pump was placed between the blow-off line leading from the mud drum of the main boiler and the lower drum of the economizer section, so that boiler water could be pumped through the economizer. Unfortunately the experiment was made

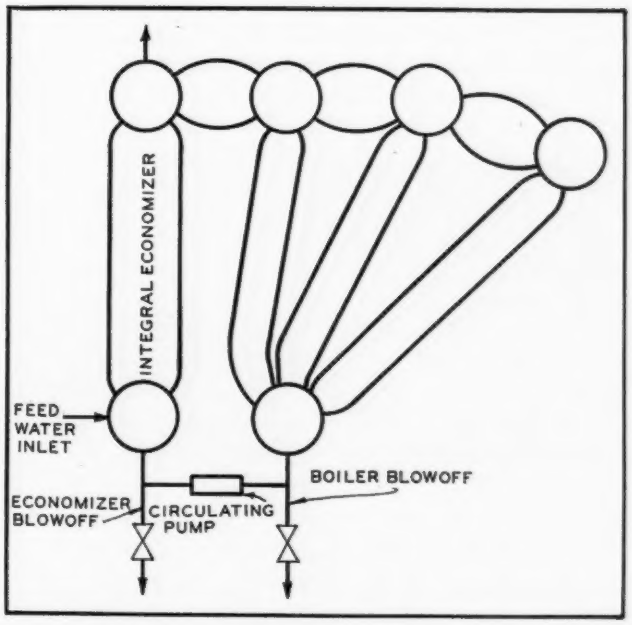

Fig. 5—Illustrating method of recirculating concentrated boiler water through integral economizer.

without being able to obtain samples of the combined blow-off water and feedwater for the determination of pH value. However, the value of the higher alkalinity obtained is demonstrated by Fig. 6, showing test samples exposed in the boiler drum with and without boiler water recirculation. While corrosion was not entirely eliminated, the value of

increasing the pH value in retarding corrosion is apparent.

In a feedwater system it is therefore not only desirable to be able to control the treatment in order to reduce the incrusting solids, but provision should be made for controlling both the oxygen content and the pH values. Obviously, since oxygen plays the most important part, it should be reduced to as low a value as possible. Under ordinary conditions, in a low pressure plant with an oxygen content less than 0.2 to 0.3 cc. per liter and a pH value of the feedwater averaging 9.5, no corrosion should be experienced. However, where steel tube economizers are installed, it is advisable to deliver the water to the economizer with no oxygen content as indicated by the Winkler test, which is possible with equipment now available.

Boiler Water

The feedwater in its cycle through the power plant concentrates in the boiler, and as a result the pH value is higher at this point than at any other point in the system, for two reasons:

1. Concentration of chemicals.
2. Decomposition of sodium carbonate to caustic soda, due to the high temperature.

The decomposition of sodium carbonate within steam boilers will be from 70 per cent up to 90 per cent, depending upon pressure.* From the decomposition of soda ash, there is formed caustic soda and CO_2. The CO_2 leaves the boiler with the steam, whereas the caustic soda concentrates, being reduced only by the blow-down. Since this decomposition has no effect upon the total quantity of alkali present, but simply converts carbonate to caustic, the pH value is increased without any increase in total alkalinity. In a plant operating with 5 per cent blow-down, the concentration of alkali in the boiler will be twenty times the concentration of alkali in the feedwater. It is for this reason that the pH values of the concentrated boiler water is usually in the neighborhood of 11 to 12, depending upon the quantity of alkali present, and it is because of this high pH value that the recirculation of boiler water to the feedwater becomes practical as a measure for the protection of feed lines, heaters, pumps, etc., from corrosion.

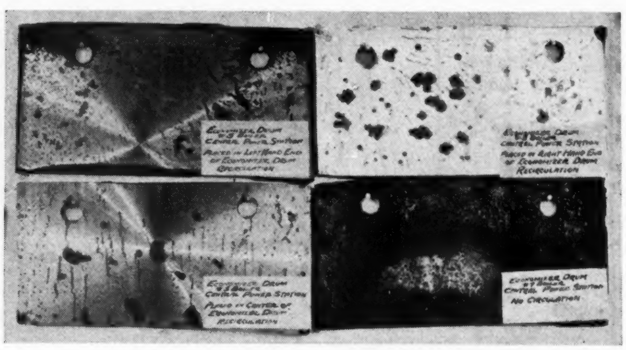

Fig. 6—Illustrating effect of recirculation of boiler water (increasing pH) in retarding corrosion.

Although boilers operate at higher temperatures than economizers, they are less susceptible to corrosion, which may be explained by the higher pH values, as well as by the fact that a boiler is a form of deaerator, since with the boiling action the oxygen and CO_2 are released and leave with the steam. However, where boiler alkalinities are low the content of oxygen and potential or half-bound CO_2 high, corrosion may progress rapidly and under such conditions, as with the use of a zeolite softener, deaeration is considered essential to remove all oxygen, free CO_2 and a portion of the half bound CO_2 from the feedwater before it enters the boilers in order to insure complete protection from corrosion.

Condensed Steam

The pH value of the condensed steam is becoming increasingly important, particularly in industrial plants where condensate is returned to the boiler feed system through long pipe lines. The acidity of the condensed steam has frequently been given as the cause of corrosion of turbine blades at the dew point and beyond.

From what has been said one can easily conceive of condensed steam being quite acid, for if we assume that a boiler generates dry steam, the water will be without contamination except for the CO_2 gas which redissolves in the condensate. The condensed steam, therefore, under certain conditions may be merely a solution of carbonic acid and in many instances the pH value of condensed steam has been well below 5, causing active corrosion, even though the oxygen content was zero.

The ability to control the pH value of the steam is rather limited, for the decomposition of sodium carbonate within the boiler cannot be prevented. In order to increase the pH value of condensed steam it will be necessary to deliver to the boiler as little carbonate radical as is practically possible. With a lime and soda softener, this control is possible to a marked degree, particularly so in the case of high pressure boilers. However, in the case of a zeolite softener practically all of the half-bound CO_2 present in the raw water appears in the feedwater, except where a deaerating heater may be used to remove as much as 30 per cent of the half-bound CO_2 along with all of the oxygen.

Once the carbonate or bicarbonate radical enters the boiler, we have no further control over the condition of the steam. In high pressure boilers where phosphate treatment is used as a supplement to the hot process softener, the pH value of the condensed steam can be greatly increased by carrying the treated water in a more caustic condition, rather than high in carbonate or bicarbonate, that is, maintaining the excess sodium carbonate low and depending upon phosphate radical for the prevention of scale. However, in any system there will be a certain amount of carbonate hardness as well as a certain amount of sodium carbonate entering the feedwater system and therefore the potential gen-

(*Continued on page 39*)

* "Conversion of Sodium Carbonate to Caustic Soda within Steam Boilers," by C. E. Joos, Nov. 12, 1929, POWER.

High-Pressure Boiler and Turbine Operation at Northeast Station*

This paper describes the installation and major problems that came up during 2½ years' operation of the high-pressure equipment at the Northeast Station of the Kansas City Power & Light Company. Reheater equipment is discussed, together with the experimental work involved in raising the steam temperature to the desired point, and incidentally obtaining a type of construction that would withstand the high furnace temperatures and give reasonable life. The effect of the reheater troubles on the use obtained from the equipment is also covered.

A general operating history of the turbine is given, dealing in considerable detail with the turbine-blade deposits. Discussion of this phase of the troubles brings out the various changes that have been made in boiler feed-water in an effort to find a relationship between boiler-water concentration and turbine-scale formation. The method used for turbine-scale removal is given.

Only minor troubles were experienced with boilers, high-pressure superheater, and auxiliaries. The effect of continued operation on boiler efficiency has been covered graphically, and the operating performance of the high-pressure equipment as well as the whole station for a typical month has been given, showing the heat consumption of the two pressure turbines, the load distribution, and the net result for the station. Considerable detail is given concerning the utility factor of the entire installation and the effect the various individual parts have had on this factor.

By J. A. KEETH
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MANY descriptions have appeared in various engineering publications of high-pressure boiler and turbine installations made in this country. Among these have been some brief comments on the high-pressure equipment at the Northeast Station of the Kansas City Power & Light Company. Most of these articles have been written from the design and construction point of view and have touched on the predicted performance only as it was necessary to justify the investment. While many of the high-pressure units have been in operation for several years, few figures covering the actual performance of the equipment have appeared. It can be safely assumed that the installations have been successful, otherwise boilers operated at the higher pressures would not have come into such wide use.

In February, 1929, a paper was presented at the Midwest Power Conference in Chicago which showed the economic basis for the selection of the high-pressure equipment at Northeast Station.[1] The boilers and turbine had been put in service only a short time previous to the presentation of that paper, hence any comments made therein had to be in the nature of predictions. More than two years have now elapsed and it should, therefore, be of considerable interest to see how near the estimates have been met in actual practice, and also to know something of the operating experiences.

Since the equipment was first put in service in January, 1929, a considerable amount of experimental work with many changes resulting therefrom, had to be done on the radiant reheaters. These experiments and changes extended over a period of nearly a year and a half and were the primary cause for the low utility factor of the equipment as a whole. It usually required one to two months to determine the effect of many of the changes made, as they frequently had to do with the ability of materials to stand up under continued high temperatures. Most of this work was completed in July, 1930, and from that time until about February of this year, operation of the equipment settled down to a regular routine which, it was believed, would be indicative of operation during the normal life of the equipment. However, in February some trouble began to develop which showed that cer-

* Presented at the Kansas City Meeting, Sept. 7 to 9, 1931, of The American Society of Mechanical Engineers.

[1] "High-Pressure Turbine Installation of Kansas City Power & Light Company," by Edwin Jowett. A.S.M.E. Trans., vol. 51, no. 1.

tain parts of the reheaters would not stand up against the temperatures obtaining and give a reasonable life. Further changes were decided upon,

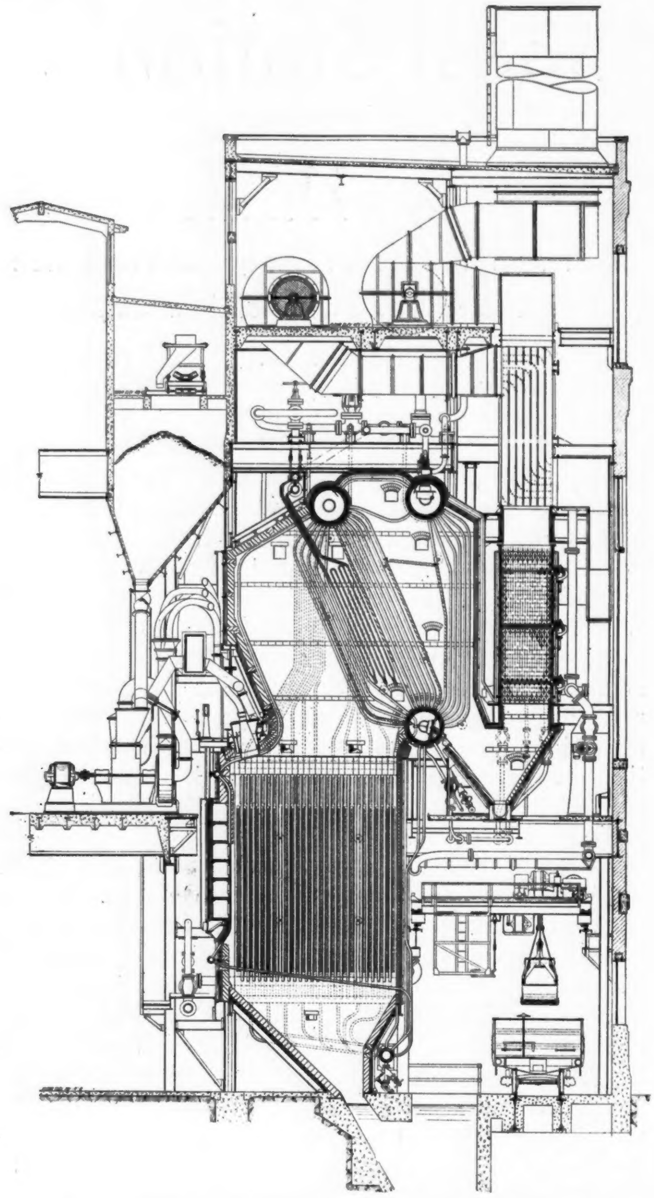

Fig. 1—Vertical section through 1400-lb. boiler unit.

the materials for which could not be obtained until June, thus leaving the answer for its entire success to some date in the future.

Equipment and Operating Conditions

The equipment consists of two 1700-hp., 1400-lb. boilers and one 10,000-kw., 1200-lb. turbine. The boilers are arranged for pulverized-coal firing, using the unit system. Furnaces are completely water walled with radiant reheaters, originally shielded by water-wall tubes, located in the side walls. The superheater is of the convection type, located in the first pass of the boiler. Fig. 1 shows a cross-section of the boiler unit.

Reheaters

The early months of the operation of this installation involved frequent interruptions. However, after the first few weeks practically all of the outages were due to reheaters. It was apparent from the start that the reheaters had insufficient surface, under the furnace conditions that prevailed, to raise the temperature of the exhaust steam to a point even approximating that desired. The many changes made in the reheaters and burners, and also air adjustments, involved much "cutting and trying." This resulted in one or the other of the boilers being out of service almost continually until the changes completed in July, 1930, had been made. Many of the changes made on these reheaters required anywhere from a week to six weeks to complete and required also, the manufacture and shipment of new tubes and other miscellaneous parts, all of which involved the customary delays in obtaining material from the mill and in shipment. After the July change was made, very reliable service was obtained from the equipment until February, 1931. At that time, leaks began to develop in the reheater tubes which, examination showed, were due to overheating of the tube walls. It was possible, however, to continue operation with occasional shutdowns until June, 1931, after which a further change was made in tube materials with the view of obtaining better life from the reheaters.

MAJOR EQUIPMENT OF NORTHEAST STATION

No.	Equipment	Manufacturer and Type	Size
2	Boilers	Combustion Engr. Corp., Type VX	16,950 sq. ft.
	Water walls	Combustion Engr. Corp., Bare and finned tube	3,050 sq. ft. per boiler
2	Superheaters	Superheater Co., Convection	2,650 sq. ft. per boiler
2	Reheaters	Superheater Co., Shielded Radiant	....
6	Pulverizers	Raymond Imp. No. 90	15,000 lb. per hr. each, 3 to each boiler
36	Coal burners	Lopulco	9—8 in. to each boiler 9—4 in. to each boiler
2	Economizers	Combustion Engr. Corp., Finned tube	10,891 sq. ft. each
2	Air heaters	Combustion Engr. Corp., Plate type	39,270 sq. ft. each
2	Boiler-feed pumps	A. S. Cameron, 6 stage centrifugal, motor driven	900 g.p.m.
1	Boiler-feed pump	DeLaval Steam Turbine Co., motor driven	900 g.p.m.
1	Turbo-generator	Westinghouse E. & M. Co.	12,500 kva.

GENERAL OPERATING CONDITIONS

Maximum pressure for which boiler is designed, lb. gage	1,400
Normal operating drum pressure, lb. gage	1,350
Maximum evaporation per boiler, lb. per hr	225,000
Normal evaporation per boiler, lb. per hr	185,000
Pressure at turbine throttle, lb. gage	1,250
Temperature at turbine throttle, deg. fahr	725
Back pressure at turbine exhaust, lb. gage	315
Superheat in exhaust at full load, deg. fahr	22
Pressure of steam out of reheater, lb. gage	290
Temperature of steam out of reheater, deg. fahr	700

While the problem of increasing the reheat temperature would appear to involve nothing more than an increase in surface, this very solution became particularly difficult to accomplish due to lack of space and excessive temperature resulting from the scrubbing action of the flame where space could be found available. Fig. 2 shows the original reheater arrangement in each side wall of each boiler. The reheater was designed for a rise of 250 deg., whereas only 125 deg. was obtained. The lack of temperature rise was due, at least in part, to the fact that the path of flame travel in the furnace exposed only a portion of the reheater surface to radiant heat. When changes were made in the firing conditions to eliminate this trouble,

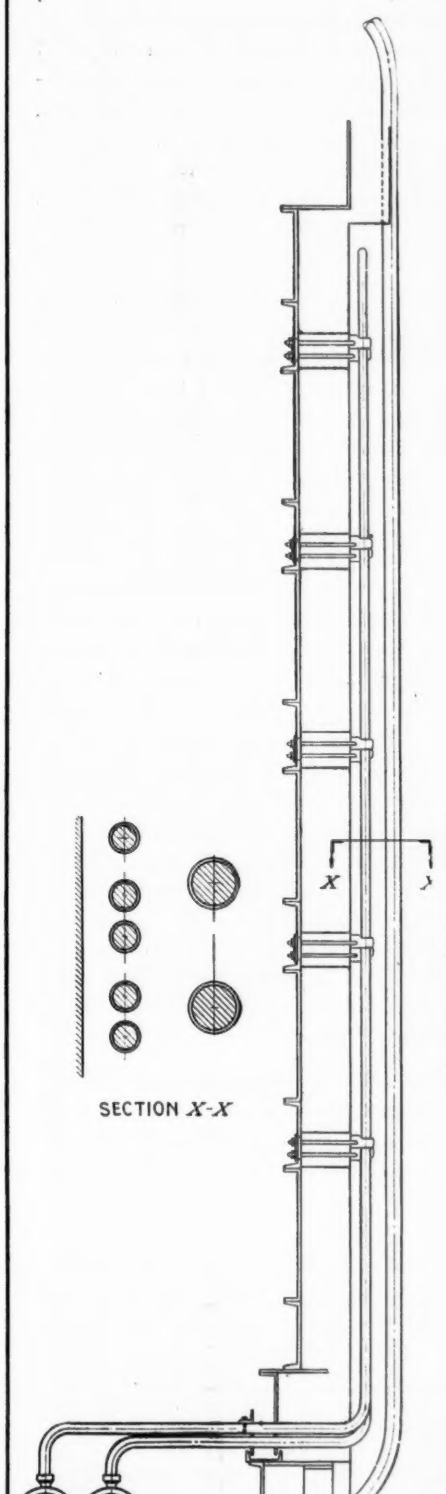

Fig. 2—Original reheater arrangement.

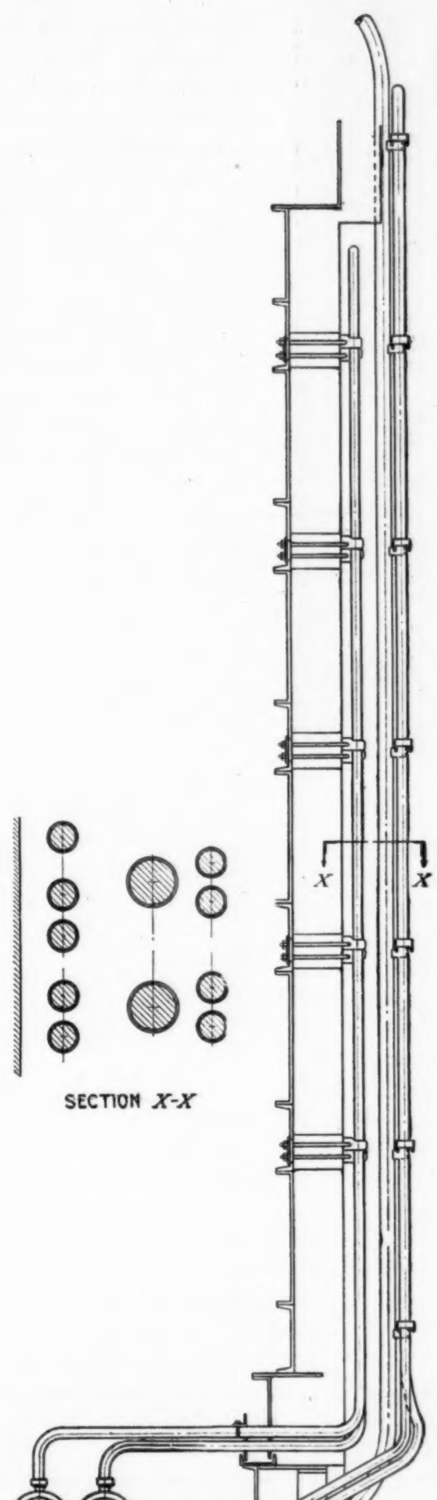

Fig. 3—First major change in reheater.

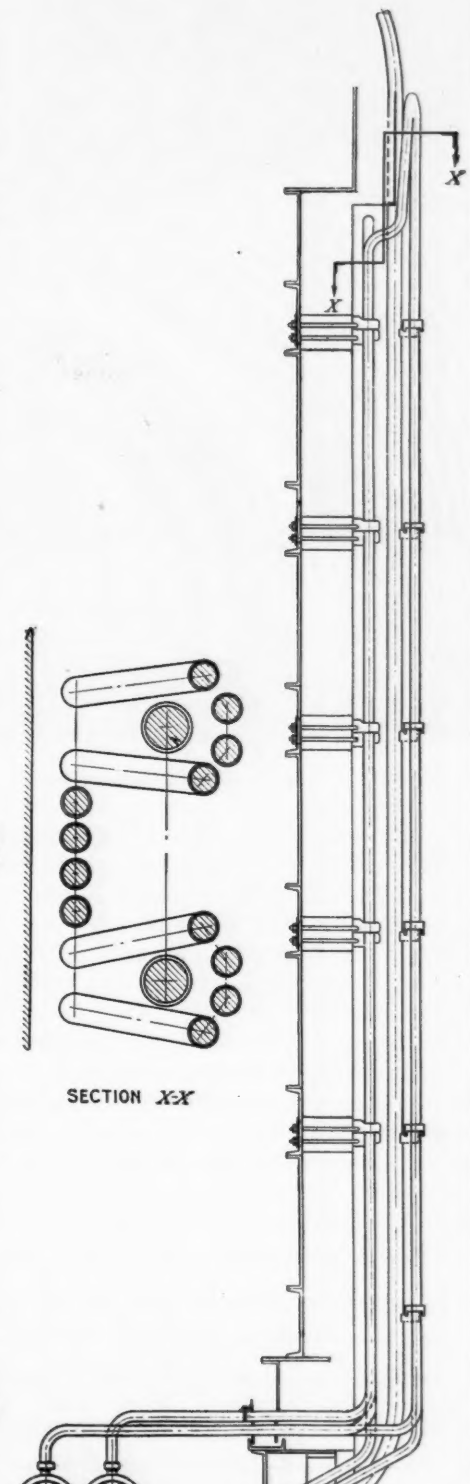

Fig. 4—Second major change in reheater.

Fig. 5—Turbine scale deposit.

large quantities of slag accumulated on the reheater and water-wall tubes which offset any gain made. Various arrangements of slag blowers were tried without effective results.

The next effort to increase reheat temperature was made by removing every other water-wall tube, thus reducing the shielding effect on the reheater tubes. While this change had some effect, it was far from adequate to meet the needs. Additional reheater elements were next attached to the furnace side of the water-wall tubes as shown in Fig. 3. These gave practically the desired temperature, but the life of the tubes in certain locations of the side walls proved to be only a few days. Thermal couples embedded in the tube walls showed temperatures on the hot or outlet leg as high as 1200 deg. These temperatures were taken at point *A*, Fig 3, so that tube-metal temperatures considerably in excess of this existed within the furnace. The additional elements were, therefore, removed from these hotter parts of the walls, and only those left in were subjected to less severe conditions. The final result was a temperature rise but little better than that originally obtained.

It was noted, however, when the change shown in Fig. 3 was made that only the outlet tube or hot leg of the element attached to the furnace side of the water-wall tube failed or showed any distress due to excessive heat. It was, therefore, believed that elements could be made with inlet legs on the outside or furnace side of the water-wall tubes and outlet legs behind and shielded by the water-wall tubes. Accordingly, this arrangement was made up and installed as shown in Fig. 4. All of the old elements behind the water-wall tubes were left in place except those that had to be removed to make room for the hot leg of the new elements. This change was completed in July, 1930, and appeared to be the permanent solution to the problem. The proper reheat was being obtained. However, as previously mentioned, occasional leaks began to develop in the furnace side reheater tube near the top after seven months of practically continuous service. Laboratory examinations of these tube failures showed that metal temperatures of around 1100 deg. had obtained near the points of failure. Sections of the tubes removed from points near the failure showed no alarming signs of overheat externally, but showed a heavy internal coating of magnetic oxide of iron.

Up to this time all reheater tubes had been manufactured from low carbon steel meeting A.S.T.M. specification No. A83-27. Inasmuch as there appeared to be, on this particular job, no other loca-

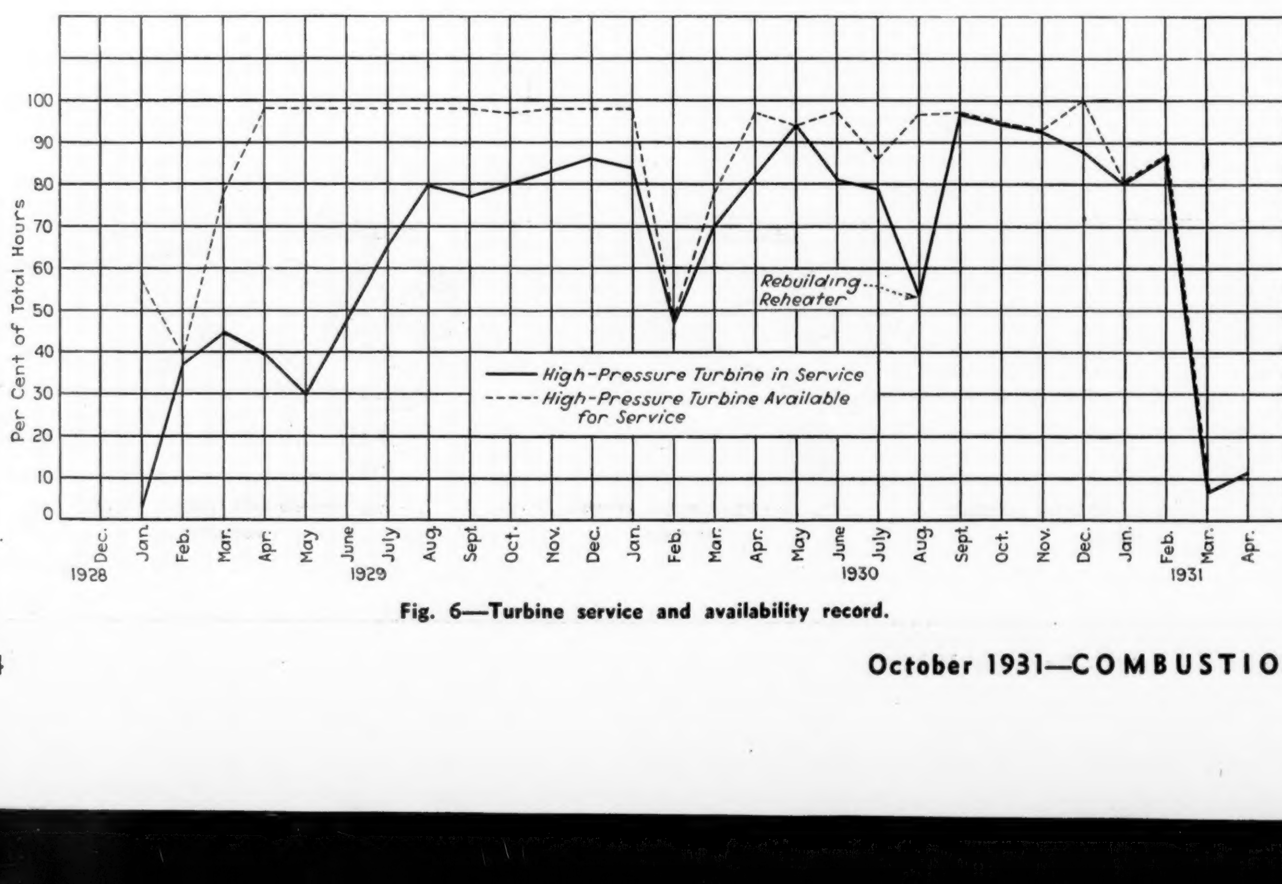

Fig. 6—Turbine service and availability record.

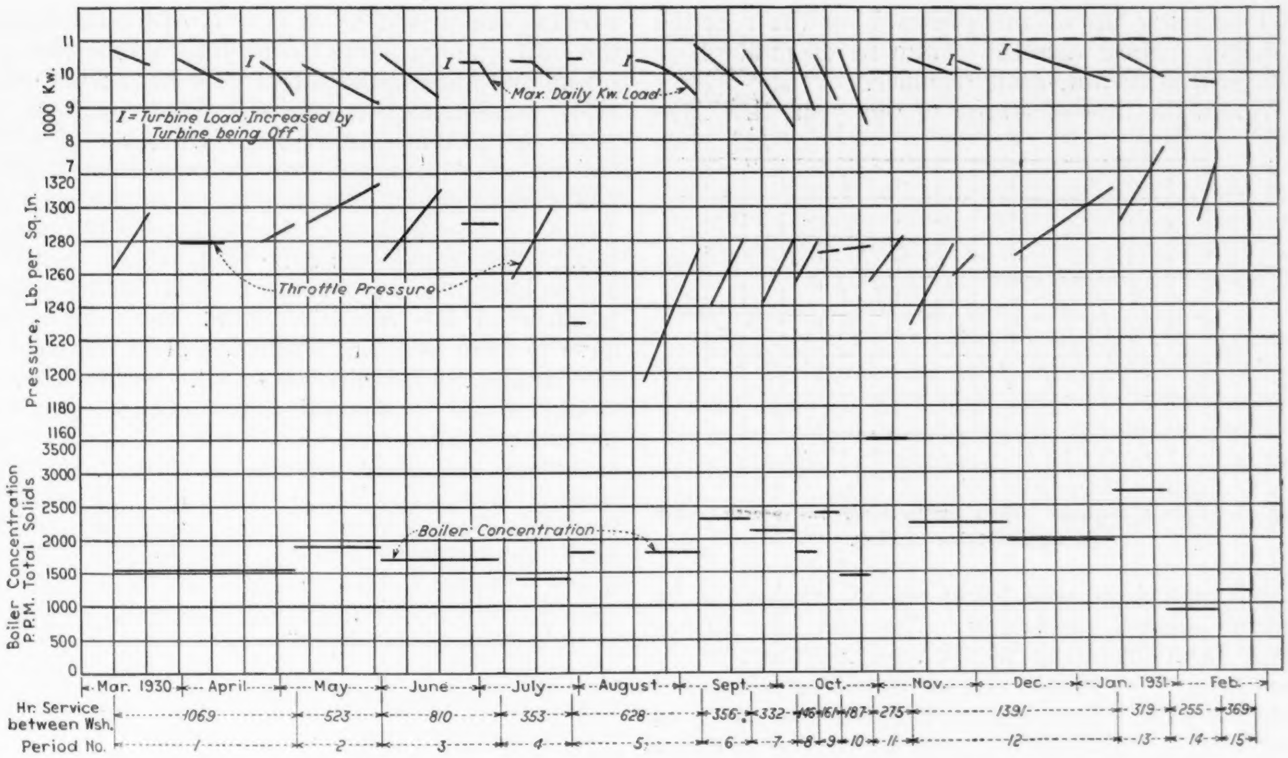

Fig. 7—Curves showing effect of scale on turbine blades.

tion for reheaters more suitable, the only solution seemed to be to find a material suitable for the tubes in the existing location. An investigation of Enduro or KA-2 showed it unsuitable at high temperature for use where fuels contained sulphur, and also that KA-2S would be unsuitable where the sulphur content of the fuel exceeded 2.5 per cent. Inasmuch as most of the fuel used at the station contains at least 3 per cent sulphur, these two alloys, representing the best of their class, were ruled out. Experience at the plant on booster superheaters shows the chrome-vanadium alloys to be little or no better than low-carbon steel.

A year's use of the experimental high-temperature superheater at Detroit had shown calorized low-carbon-steel tubes quite effective in resisting high temperatures both outside and inside the tube. While the year's use seemed to show some thinning of the outer calorized coating, it was believed to be in such condition that a very reasonable life could be expected from the calorized units. As these metals just mentioned seemed to cover the better known high-temperature resisting metals for tubes, it was decided to try the calorizing. Accordingly, two complete sets of elements were made up to the same form as those shown in Fig. 4, except that the leg attached on the furnace side of the water-wall tube was calorized both inside and out. The two reheaters so equipped were put in service the early part of August of this year, and will, it is confidently believed, prove the final solution to the reheater trouble.

The preceding outlines only the major changes made to the reheaters. Many minor changes were made on the first and second installations such as the use of orifices for changing steam distribution, alteration of burners, and finally the addition of auxiliary burners near the bottom of the side walls. All of these changes, particularly the latter, have contributed their share in the solution of the problem. The last-mentioned item, namely the auxiliary burners, has been particularly effective in improving furnace conditions and reducing slag. While all of the changes were more or less of a "cut-and try" nature, they were all based on careful experiment and observation which took much time to accomplish.

Particular reference has been made to this reheater trouble because of its bearing on the utility factor of the equipment. During the first six week's operation, there were, of course, many other difficulties which caused some outages. These were, however, of a nature more or less expected with the starting of new equipment and were soon overcome.

High-Pressure Turbine

The dependability or service availability of the turbine has been high. Some trouble was experienced during the first three months with balance of the generator rotor and turbine alignment. However, after correcting these troubles, its service availability was nearly 100 per cent until its first inspection after 13 months' use. With the exception of a few minor items, the turbine was found to be in perfect condition. During the second year the turbine continued to give almost equally good service from the mechanical standpoint. However, trouble experienced during the first year from scale deposit on the blades continued throughout this second year, necessitating frequent washing. This trouble evidenced itself by loss of load and a grad-

ual building up of the pressure on the reaction blading. More detailed comment is made later concerning turbine-scale troubles.

About the first of March of this year, the high-pressure turbine was taken out of service for its second annual inspection. The unit had apparently been operating well up to this time, but it had been noted that the last two washings had not had the usual effect in increasing its load-carrying capacity or reducing the pressure on the reaction blading. It was presumed that the blades were badly scaled up and would require scraping. On opening the turbine, it was found that many of the wedges holding the revolving impulse blading had come out, and some had passed through the reaction blading, bending it so badly that the area through the blading was greatly reduced. It was this condition, and not the scale formation, which had caused the last load reduction. The manufacturer felt that the wedges had been loosened by the sudden temperature changes while washing the turbine and recommended returning the spindle to the factory to have a different type of wedge installed which would be less subject to this objection.

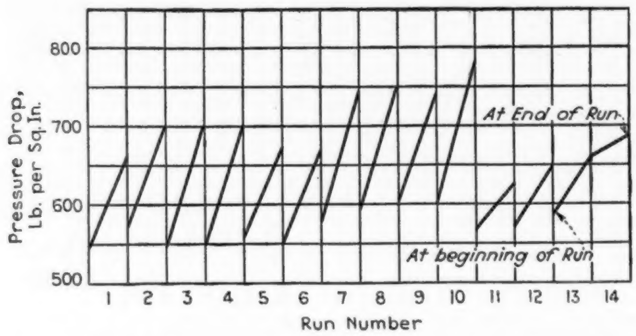

Fig. 8—Curves showing effect of washing on pressure drop through reaction blading.

This was accordingly done, and in addition some field changes were made to the wedges for the nozzle and impulse blades. Some defective material used in the high-pressure and dummy packing had also failed, causing considerable damage to the remainder of the packing. New packing was installed on the high-pressure end of the unit. There seems to be little doubt that the troubles which appeared at this inspection have been permanently corrected. There was at no point in the unit any evidence whatever of water cutting or erosion, both the stainless-steel impulse and nickel reaction blading being in perfect condition. There had been no leakage in the casing joint. The trouble with the wedges was probably due to lack of knowledge on the part of the manufacturer of the conditions that the unit would have to meet in being washed, and in the case of the packing, to defective material. Neither case of trouble could be attributed to the high operating pressure.

During the early months of this year some trouble was experienced with the oil-balanced throttle valve. Several changes were made which have apparently corrected the troubles. These troubles with the throttle valve accounted for the decrease in the availability of the turbine just prior to the March overhaul.

Curves, Fig. 6, show the amount of time the turbine has actually been in service and also the time it has been available for service.

Turbine-Blade Scale

The trouble with scale deposit on the turbine blades has been, and still is, sufficiently serious to warrant somewhat detailed comment.

No scale deposit has ever been formed in either the primary superheater or reheater tubes. It seems to form only on the last three rows of blades of the high-pressure turbine and again in the lower stages of the low-pressure turbines operating off the exhaust of the high-pressure unit. The analysis of the scale from both locations is essentially the same and shows it to consist largely of silicates of iron and aluminum which are quite insoluble in water. Fig. 5 shows the scale deposit found on the last row of high-pressure turbine blades at the time of the first annual inspection of the turbine.

In general, the scale has been quite effectively removed by washing the unit with saturated steam when operating at less than 100 r.p.m., and exhausting to atmosphere. Due to the insoluble

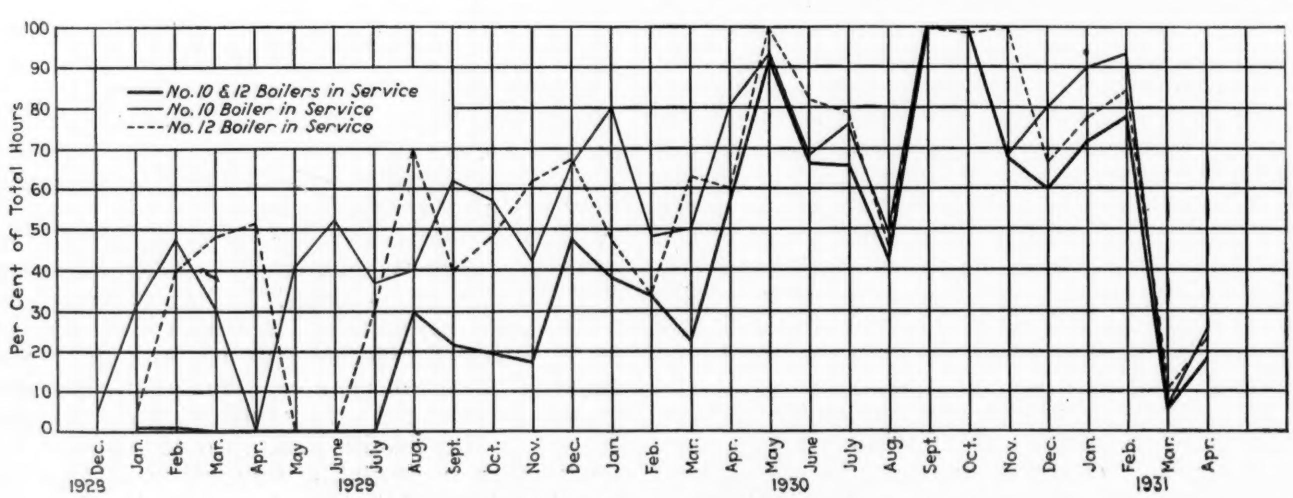

Fig. 9—Boiler service and availability record.

character of the scale, it is believed that the washing effects a cracking of the scale due to temperature change, and also an actual scrubbing action due to the entrained water. In some cases, allowing the unit to stand idle for sufficient time to become cold has proved quite effective in scale removal. Here the action must be purely a weathering or cracking.

Curves, Fig. 7, show the operation of the turbine from March, 1930, to March, 1931, divided into periods between washings. On these curves are plotted the maximum possible daily kilowatt load, throttle pressure, and boiler-water concentration. The letter *I* opposite the maximum daily loads indicates the increase in load due to the unit having been out of service at least long enough to cool off. The failure to increase the load by washing as shown the latter part of January and middle of February was explained by the bent condition of the turbine blades as found on inspection and as previously described. Fig. 8 shows the effect on the pressure drop through the reaction blading by each washing.

An enormous amount of experimental work has been done in an effort to eliminate the scale formation on the turbine blades. While it may seem that a solution should have been reached by this time, it must be remembered that the collecting of data for a study of this kind requires much time. This same problem of turbine scale is confronting some of the largest plants in the country and is commanding the study of many research engineers, including Dr. Straub of the University of Illinois. He estimates that his investigation program will take nearly two years to complete. In general, the experimental work done here and the conclusions drawn therefrom are enumerated below:

1. Numerous tests were made to determine the carry-over with various boiler-water concentrations. Results showed no apparent difference in carry-over with concentrations varying from 3600 p.p.m. down to 100 p.p.m.
2. Tests were made to note the effect of water level and rating on carry-over. No difference was observed within reasonable operating limits.
3. All make-up going to the high-pressure boilers was eliminated to reduce concentration and impurities. Results showed no improvement.
4. The phosphate feed was reduced and the PO_4 in the boiler water was cut from 60 p.p.m. to 3 p.p.m. This reduction has showed no benefits.
5. The concentration was reduced again to about 200 p.p.m. to see if the carry-over tests in item 1 were correct. Scale formation was apparently just as rapid.

A definite plan for further investigation of the turbine-scale trouble along other lines has been laid out and is in progress, and it is hoped that a solution will soon be found.

Boilers and Auxiliaries

The boilers, water walls, superheater, and economizer have developed no defects and give no indications that maintenance will be any higher than on the 300-lb. pressure boiler units in the plant. There have been three boiler-tube failures—the first due to a defective tube, the second damaged due to the first failure, and the third due to almost complete stoppage of circulation in the tube by mud resulting from a serious condenser leak. The tubes are absolutely free of scale and have never been turbined. Careful and correct control of the oxygen content of the feedwater has successfully prevented any pitting or corrosion either in the boiler, water walls, or economizer.

Boiler auxiliaries which include pulverizers, forced- and induced-draft fans, and boiler-feed pumps have proved quite as dependable as the low-pressure service and, therefore, require no particular comment. The same can be said of feedwater regulators, valves, pipe joints, and piping.

Reference has been made in several places to the

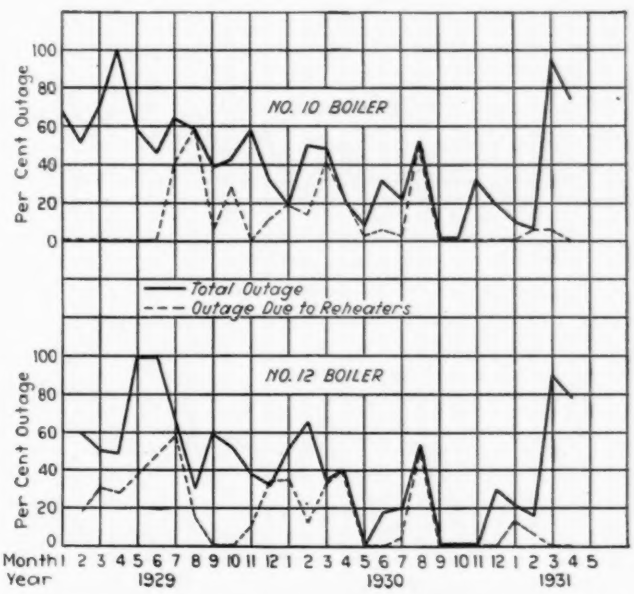

Fig. 10—Boiler outage due to reheaters.

service factor of the equipment and a curve is given to show the service and availability of the turbine. Curves, Fig. 9, show the service obtained from each of the high-pressure boilers. As graphic proof of the statement made regarding reheaters, a curve, Fig. 10, is shown to indicate the percentage of outage due to reheaters. A gradual increase in the service will be noted up to the time of the completion of the reheater rebuilding in June, 1930, after which time, and up to the turbine overhaul in March, 1931, a condition obtained which marked a very good service record. The period of outage during March and April was due to turbine repairs as previously described. After the reheater troubles are permanently repaired, continuous runs for the boilers of from 100 to 125 days will probably mark the practical limit. After such intervals, some repair work or replacements are required on the induced-draft fans. A general cleaning of the boiler and air heater has proved advisable and usually some minor refractory repairs must be made after such a period.

There is very little change in the operating ef-

ficiency of the boiler units over continuous runs of 100 days or more. This is very clearly indicated by Fig. 11, which shows all essential operating pressures and temperatures for each day throughout a 106-day operating period. A study of this curve sheet indicates that considerable credit should be given to the methods which have been devised and utilized for removing slag while in service, particularly when the type of coal used is considered. The coals contain more than 15 per cent low-fusing ash and have a high sulphur content. Space limitations restricted the furnace size such that a normal combustion rate of nearly 20,000 B.t.u. per cu. ft. is maintained without the use of turbulent burners. The slag problem at first appeared the most serious factor against even reasonably long operating periods and its solution has been the result of untiring effort toward better combustion and improved slag removal facilities. The nine 4-in. auxiliary burners near the bottom of the furnace have done much toward obtaining more complete combustion within the furnace proper, and have thus greatly reduced the slag deposit within the boiler itself.

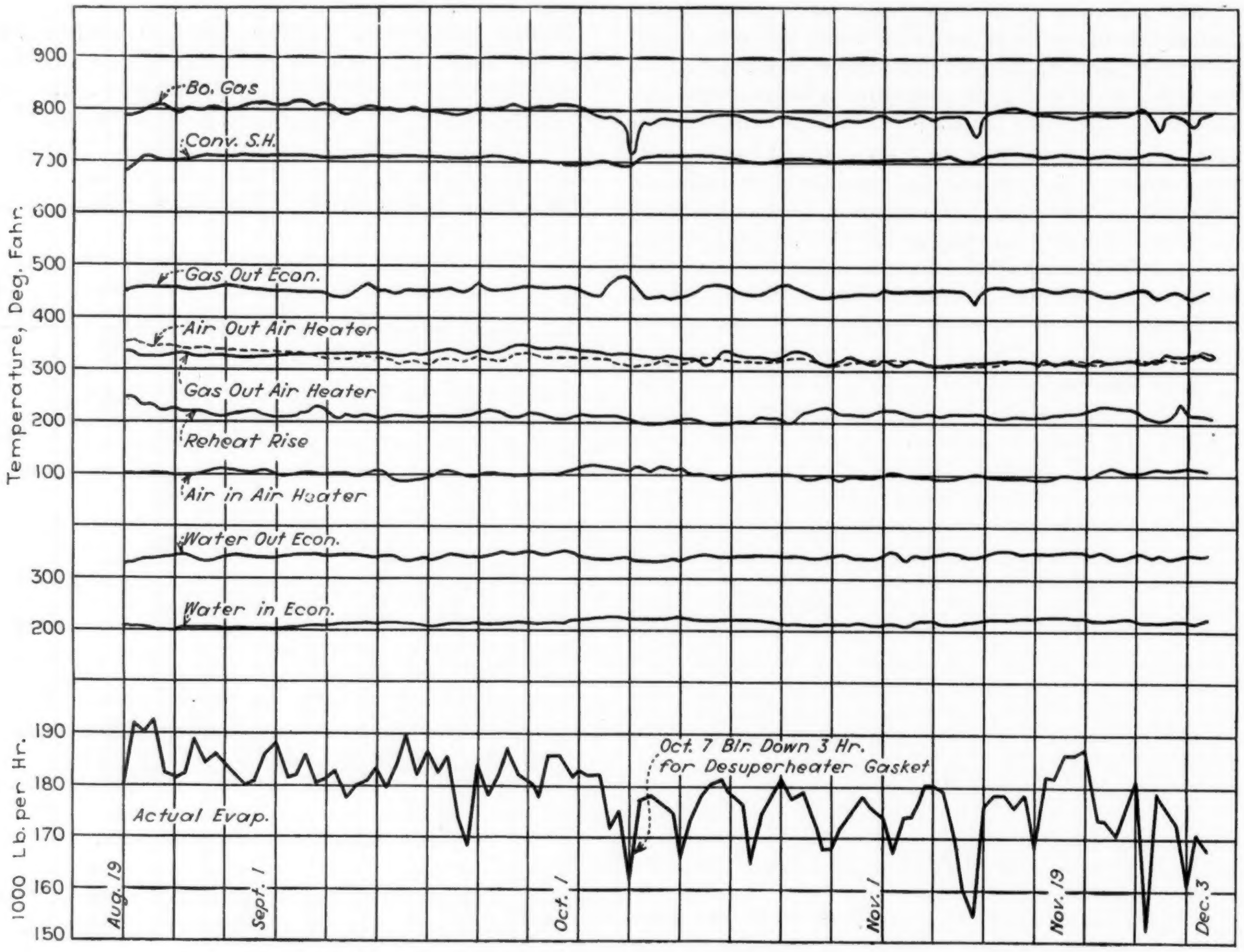

Fig. 11—One hundred and six day run of 1400-lb. boiler unit.

From the time the two high-pressure boilers first came into service up to May, 1931, a period of 28 months, they were out of service 42.6 per cent of the time. The reheaters caused 40 per cent of this outage. If the reheaters had given no trouble, the boilers could have been in service 74.4 per cent of the total time, even including the earliest operating period. The boilers were out of service during March and April, 1931, for overhauling of the turbine, or 6.5 per cent of the 28-month period. If this outage along with the reheater trouble were not charged against the boilers, they would have been available 80.9 per cent of the time. For the year 1930 alone, the boiler availability was approximately 85 per cent.

Operating Economies

Now that it has been fairly well established that the equipment is dependable and that the original estimate that the equipment could be operated at an annual load factor of about 80 per cent is reasonable, it should be of interest to note what the actual economy of the installation has been. Accordingly the following data taken from the monthly operating report of Northeast Station for September, 1930, shows what is being accomplished by the operation of this unit. It should be borne in mind that the efficiency of this cycle was somewhat impaired during this month and also during several previous months by the reduction in

output of the high-pressure unit by the scale deposit on the blades. When this trouble is corrected, results should be somewhat better.

NORTHEAST STATION PERFORMANCE, SEPTEMBER, 1930

Total power generated, kw-hr.	39,407,000
Net output, kw-hr.	36,705,700
Generated on high-pressure turbine, kw-hr.	6,561,000
Generated on 300-lb. turbines on exhaust from high-pressure unit, kw-hr.	22,150,000
Generated on 1200-lb.—300-lb. combination, kw-hr.	28,711,000
Generated on 300-lb. units with steam from 300-lb. boilers, kw-hr.	10,696,000
Auxiliary power used by high-pressure boilers, kw-hr.	1,334,600
Auxiliary power used by 300-lb. units operating on exhaust from high-pressure unit, kw-hr.	735,000
Total auxiliary power used by 1200-lb. = 300-lb. combination, kw-hr.	2,069,600
Auxiliary power used by 300-lb. units with 300-lb. boilers, kw-hr.	632,400
Heat rate of high-pressure unit based on 82.5 per cent boiler efficiency, B.t.u. per kw-hr.	4,400
Heat rate of 300-lb. units operating on exhaust from high-pressure unit, B.t.u. per kw-hr.	15,955
Heat rate of 300-lb. units operating with 300-lb. boilers,[a] B.t.u. per kw-hr.	17,206
Heat consumption high-pressure unit (6,561,000 × 4400), million B.t.u.	28,869
Heat consumption 300-lb. units on exhaust of high-pressure unit (22,150,000 × 15,955), million B.t.u.	353,390
Heat consumption of 300-lb. units on steam from 300-lb. boilers (10,696,000 × 17,206), million B.t.u.	184,030
Total consumption, million B.t.u.	566,289

[a] Actual 300-lb. boiler efficiency 76.5 per cent due to large amount of banking.

$$\text{B.t.u. per kw-hr. generated} = \frac{566{,}289{,}000{,}000}{39{,}407{,}000} = 14{,}370$$

$$\text{B.t.u. per kw-hr. output} = \frac{566{,}289{,}000{,}000}{36{,}705{,}700} = 15{,}414$$

Had there been no high-pressure equipment operated at the plant during this month, the 300-lb. pressure boilers would have operated at an overall efficiency including banking of about 79 per cent instead of 76.5 per cent as shown, lower banking losses and better boiler load factor accounting for the difference. This difference in boiler efficiency along with the normal auxiliary power consumption would have resulted in a plant heat rate of 17,600 B.t.u. per kw-hr. net output. This is a reduction for the plant heat rate of 2186 B.t.u. per net kw-hr. due to the use of the high-pressure equipment during this particular month. This is a reduction somewhat in excess of that originally calculated. It was, however, obtained under more favorable conditions; namely, the proportion of total load carried on the 1200-lb.-300-lb. combination was higher than that originally anticipated. Failure of the system load to increase, due primarily to the business depression, has brought about this condition.

The results obtained from the high-pressure equipment has been such, however, that there is no question regarding its justification. The cost of the installation was about $1,650,000, and based on the actual operating economy of the equipment a load factor of 36.5 per cent would result in a saving which would justify the increase in investment over 300-lb. equipment using coal at the original calculated cost of 67,000 B.t.u. for 1 cent.

The situation can be summarized by saying that, all things considered, this company is satisfied the investment was justified and that operation at this pressure is entirely practical. Unless newer and unforeseen developments prove better, or unless the cost of fuel has become too low to justify the investment, when the time comes for further expansion of this station, the use of additional 1200-lb. equipment will be made.

Hydrogen Ion Determinations in the Steam Plant

(*Continued from page 30*)

eration of a certain amount of CO_2 with the steam.

In illustration of the effect of low pH in condensed steam, the author recently found that serious corrosion was taking place in the return lines of a pressure heating system. The make-up was treated by zeolite and returns as well as make-up were deaerated, tests showing zero oxygen. The steam was generated at [illegible]100 lb. per sq. in., which was reduced at the heating system main to 30 and 5 lb. pressure. To increase the pH value of the returns, it was recommended that concentrated boiler water be sprayed into the steam lines, using the differential pressure between the boilers and mains to effect the spraying. Since there are no traps between the boiler and the return lines, all the alkali so introduced will come back with the returns, thus raising the pH value without any increase in boiler alkalinity. The same procedure has been recommended in an industrial plant using desuperheated steam where corrosion occurs in the condensate return lines. In this instance, the alkali will be introduced through the desuperheater spray.

Plants using reciprocating engines frequently remove oil from the condensate by the addition of alum and alkali and if control of the pH value is not maintained, there may be deterioration of internal parts. This is particularly true if the alkali used for precipitation of the coagulant is derived by mixing a cold softened make-up water with the condensate prior to filtration. Under these circumstances the high oxygen content of the softened water, coupled with the high temperature condensate, may lead to corrosion.

It is quite evident that in the design, selection or installation of a feedwater conditioning system, not only should we take into consideration the degree of softening, cost of treatment and the design of the equipment, but we should also know the pH values that can be attained in the operation of this system, for pH goes hand in hand with oxygen in corrosion problems. The higher the oxygen, the higher the pH value will have to be, consequently, and conversely with a lower oxygen content the pH values may be lower. Because of the importance of pH values in the control of corrosion, engineers would do well to make systematic tests to learn the causes of corrosion, if any, or to observe the interesting changes that take place in the feedwater in the circuit from its raw state to its return as condensate. As an illustration, the following table (page 46) summarizes pH values and other essential tests taken from the log of a large textile plant using a sedimentation basin, filters, zeolite softeners and deaerating heater.

Such systematic tests as those illustrated give to the operating engineer a bird's eye view of the chemical character of these water supplies. Thus

(*Continued on page 46*)

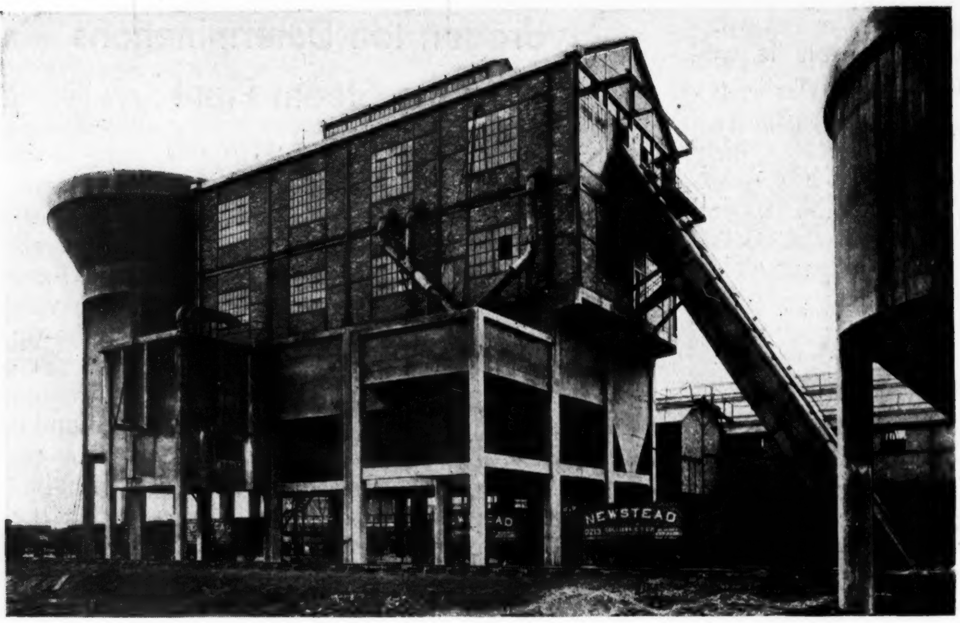

Fig. 1—Coppee coal washing plant at the Newstead Colliery Company, Ltd.

European Practice in Coal Cleaning

The Latest Designs of Modern Jig Washing Plants

By
DAVID BROWNLIE,
London

Coal cleaning is practiced in various European countries on a much wider scale than in the United States. Mr. Brownlie tells the story of this development, pointing out that its widespread adoption, particularly in certain countries, has been to some extent compelled by the inferior qualities of the coals of those countries. Nevertheless, the results have been so beneficial that the practice has continued to grow on its own merits. This practice is also growing rapidly in the United States having been stimulated by the increasing popularity of oil and gas fuels which has forced the coal industry to improve its product.

RAPID progress is now being made in Germany and Belgium, and to a very considerable degree also in France and Great Britain, in the washing and cleaning of coal, primarily of course to reduce the ash content and give a uniform quality. At present, the total world production of coal and lignite is approximately 1,500,000,000 metric tons* per annum of which the United States produces about 540,000,000 tons, Germany 330,000,000 tons (including 170,000,000 tons of lignite), Great Britain 255,000,000 tons, France 54,000,000 tons, and Belgium 26,000,000 tons. For the purpose of discussion, we can assume the average ash content of the 1,500,000,000 tons of coal to be 15 per cent which by modern washing and cleaning methods could be reduced to 4 to 5 per cent. That is the world is cursed with the carriage, handling, and disposing generally, at great net cost and inconvenience, of the huge amount of 150,000,000 tons of useless ash every year which could all be taken out at the pit head. In addition, the ash in coal causes, in average practice, a serious loss in the efficiency of combustion, probably at least equivalent to 5 per cent of the coal burned, or 75,000,000 tons, and probably very much more.

The general position at the present time is that about 85 per cent of the whole of the coal output of the Belgium mines is washed, with say 75 per cent in Germany, 48 per cent in France, and 25 to 28 per cent in Great Britain.

In the United States, only a small percentage of the coal produced is cleaned, probably not more than 5 per cent of the total output. Most of this is in Alabama, with not more than about 2 per cent in other well known coal areas, such as Penn-

* Metric ton = 2,204.62 lb.

sylvania, Western Virginia, and Illinois. Germany today is pre-eminent in this field with by far the largest equipment of coal cleaning plant in the world, and a huge output of about 130,000,000 tons of washed and cleaned coal per annum, while much of the pioneer work in plant and equipment, as well as research, is German.

Since the World War there has also been an enormous increase in coal cleaning in France and Belgium, partly because a considerable proportion of the mines were destroyed and then rebuilt on the latest principles. Also every attempt is being made on most scientific lines, as in Germany, to develop the sale of a standard quality clean coal, and Government and other national authorities, such as the Belgian State Railways, purchase coal on a sliding scale according to the ash content. It must be remembered, however, that the total output of cleaned coal in France and Belgium is not as great as in Germany, being 26,000,000 tons and 22,000,000 tons per annum respectively. Also so far as Great Britain is concerned, although the percentage figure washed and cleaned is only from 25 to 28 per cent, this corresponds to an output of 67,000,000 tons per annum, much more than France and Belgium put together.

In addition, coal cleaning is now making rapid strides in Great Britain, the most advanced area being South Yorkshire with a total production of 33,000,000 tons per annum, where about 85 per cent of the output of "nuts" and "smalls" is now washed and cleaned, whereas in 1910 the figure was only 33 per cent.

The more extensive development of coal cleaning in one country as compared with another has of course been due, at least to a partial extent, to the quality of the coal available. Washing and cleaning was first adopted for by-product coke oven practice, and it may be remembered the latter industry originated in France and Belgium in 1850 to 1860 and soon developed in Germany also because of the failing supply of good grade coking coal suitable for the beehive oven, whereas these conditions did not obtain in Great Britain and the United States.

In general, the coal mined in Germany, France, and Belgium is inferior to that of Great Britain, being in thinner seams and more friable. Consequently washing and cleaning was adopted to compete with British coal and the advantages alike for the producer and the consumer have proved to be so great that the British colliery industry is more and more adopting the same methods in spite of possessing better coal.

It is largely because of the better quality of the coal in the United States that so little coal is cleaned there, except in Alabama with comparatively friable coal. This, of course, does not detract from the fact that Germany, Belgium, and France, although in the first place compelled by necessity, have developed cleaning on such scientific and efficient lines as to revolutionize the whole situation of coal selling and to render inevitable the cleaning of most of the world's coal in the immediate future.

It is not generally realized, however, that British pioneers have played an important part in the development of coal cleaning during the past three-

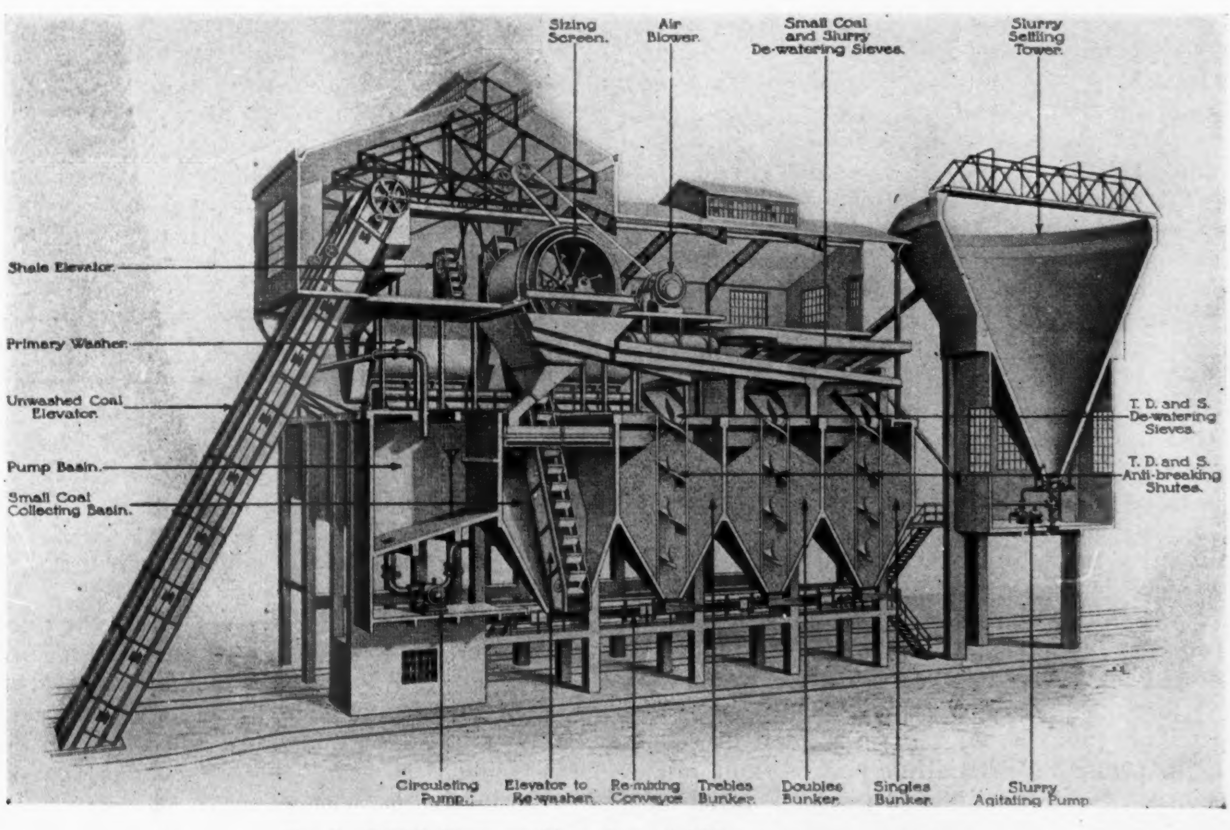

Fig. 2—British Baum washing plant of 150 tons per hr. capacity.

quarters of a century, especially as regards trough washers, upward current washers, and concentrating tables, in spite of the important work that has been accomplished in this field by German fuel technologists. Noteworthy also is the fact that modern methods of dry cleaning have largely been developed in the United States.

There are now available many different methods of coal washing and cleaning, such as jig washers, upward current washers, trough washers, Rheolaveur washers, use of solutions of higher specific gravity than water, froth flotation, and, of course, hand picking and screening.

In the present contribution, it is the intention to deal with the latest developments in jig washers as used to the extent of several thousand installations, particularly in Great Britain and Germany.

The basic principle of coal cleaning by washing is, of course, to submit the coal to the action of water in such a manner that the heavier mineral impurities sink and the pure coal tends to float, thus effecting a separation. In jig washing this is carried out in specially constructed troughs or tanks containing flowing water which is subjected to a rapid agitating or pulsating motion so that the dirty coal is thrown into suspension for short periods of time in succession, the coal being carried forward by the current of water and the dirt sinking. This agitation of the water is effected by means of reciprocating plungers or compressed air, the latter, however, being the more modern method, all the earlier jig washers such as the Luhrig and the Humboldt still using the plunger principle.

The most famous jig washer is the "Baum," introduced in Germany in 1892, using compressed air. In 1901 Baum originated another great advance, that of washing all the mixed crushed and small coal direct without preliminary screening or sizing in the dry state as in previous jig washing practice.

After 1905, rapid progress was made in Germany and Mid-Europe with the Baum washer, and in Great Britain equipment of this character, with various modifications and improvements, is now manufactured by a number of firms such as for example, Simon Carves, Ltd., Cheadle Heath, Manchester, the Coppee Co. (Great Britain) Ltd., London, H. Greaves and Co., Ltd., Derby, and Norton Tividale and Co., Ltd., Tipton, (Staffordshire).

Essentially a modern Baum coal washing plant consists of an inclined bucket elevator for the entering unwashed coal, primary washers, elevators for handling the separated dirt, screening equipment to separate the washed coal into different sizes, often a rewashing plant to deal with the smalls or smudge below ⅝-in. size a second time if required as for by-product coke, and a large overhead tank, generally of concrete, for allowing the very fine slurry to separate from the water by gravity. Included also is a complete equipment of air valves, air blowers, with the air at about 2 lb. per sq. in. pressure, circulating pumps, and pipe connections. On these lines, the mixed, crushed, and small coal, in all sizes up to say all through 4 to 5 in. screen, is taken direct without any dry screening and washed from almost any ash content say from 7 to 25 per cent down to an average of about 3½ to 5 per cent and also screened auto-

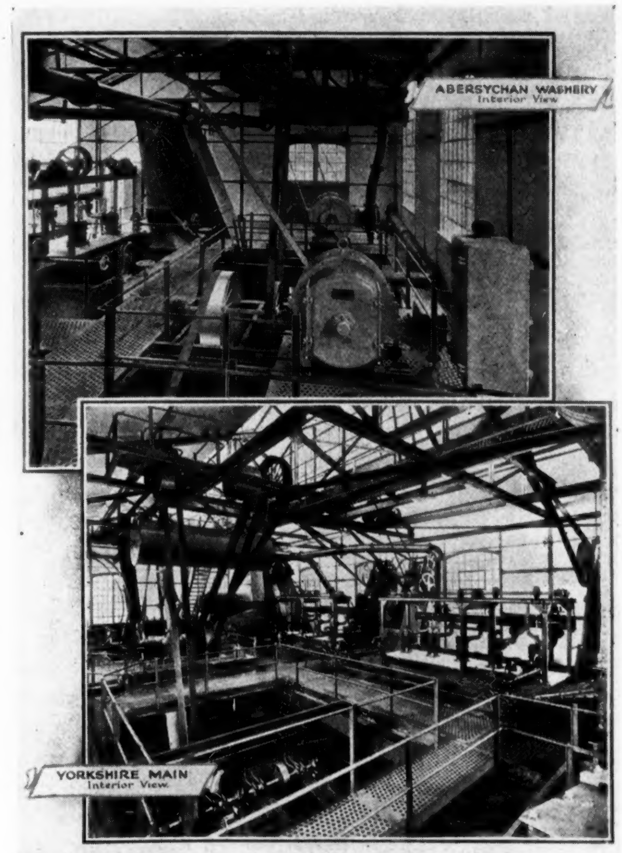

Fig. 3—Interior views of the washing plants of the Abersychan and Yorkshire Main collieries.

matically to the different sizes, while the capacity is generally within the range of say from 50 to 350 tons of coal per hour.

The Simon Carves Company commenced to construct Baum washers in 1903, and they state they have now designed and built about 120 complete British plants having an aggregate capacity of 10,445 tons of coal per hr., which if operated for 24 hours day and night would wash the whole of the output of small coal in Great Britain. Further, we are informed that 54 of these plants have been erected during the past 4 years, representing a total capacity of 5,545 tons per hr., with a total capital expenditure of $5,000,000, many of the larger installations having a capacity of from 150 to 200 tons of coal per hr.

A sectional elevation of a typical British Baum washer box as made by Simon Carves, Ltd., is illustrated in Fig. 4, being a single box capable of dealing with mixed slack coal in amount up to 130 tons per hr. If a larger throughput is required, and when the smalls are to be used for by-product coke oven work, an additional operation is, however, included, in which the fine coal below ⅜-in. is subjected to rewashing.

The compressed air enters by the air valves at

the top, of which four are fitted, and passes direct to an air chamber. When the piston, which has a number of valve ports, is at the opposite end of the stroke, these ports are open, thus allowing the compressed air to be discharged direct to the atmosphere. The continuous operation of these valves on the lines indicated gives the required pulsating motion to the water in the washing chambers.

The raw coal enters by the inlet F shown on the left and is deposited on the bed K in the first section of the box E. From here the heavy dirt collecting on the bed is taken away continuously through an adjustable sluice gate G, passing down the chute H into the dirt elevator J of a vertical bucket elevator for discharge. The partially clean coal, still retaining the lighter dirt, then overflows into the second part of the washer box M on the right, the dirt now collecting on the bed R and being taken away continuously by the adjustable sluice gate O on the right, passing down into the chute P for delivery to the chain bucket elevator Q, also for discharge, while the clean coal passes out at N, almost entirely free from ash and dirt. Further, a certain amount of extremely finely divided dirt goes through the perforated beds K and R and settles at the bottom of the washer box, from where it is removed by screw conveyors L and S and discharged also to the respective bucket elevators J and Q. From the outlet N, the clean coal

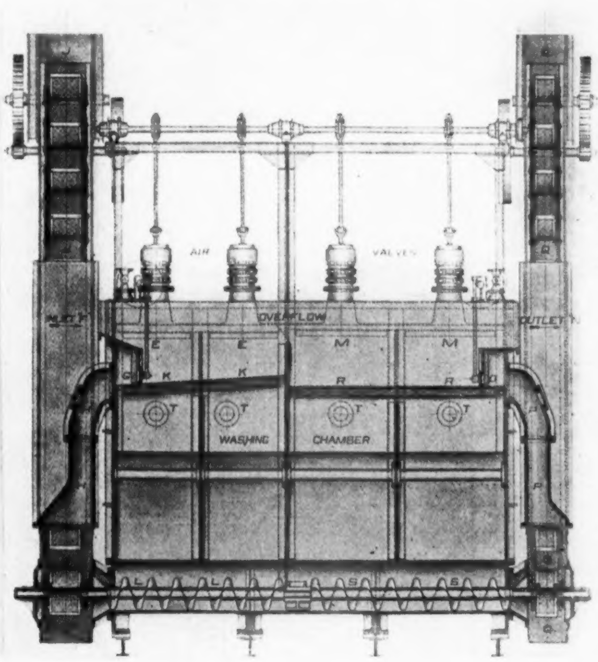

Fig. 4—Sectional elevation of British Baum Washer Box.

then flows through classifying screens or direct into bunkers, as required, while a continuous flow of wash water enters by the pipes T, the amount of water as well as air being capable of accurate adjustment to give the exact results required.

The valve pistons operate at about 40 to 55 strokes per minute and it is claimed that the wear and tear is so small that in many cases the valves have been operating for 15 years.

A washer of 150 tons of coal per hr. capacity is about 16 ft. 6 in. long and 11 ft. 6 in. wide in the first washer box, having a ½-in. screen, while in most cases a rewasher box is equipped with a $\frac{3}{16}$-in. screen about 16 ft. long by 11 ft. 6 in. wide, having a total washing area of 374 sq. ft., that is 2.5 sq. ft. per ton of coal washed per hour, these dimensions, however, being varied according to the conditions.

The Coppee Co. (Great Britain) Ltd., have also supplied many Baum washing plants, typical of which is an installation at the Loanhead Colliery 7 or 8 miles from Edinburgh, belonging to Shotts Coal and Iron Co., Ltd. This installation has a throughput of 150 tons of coal per hour, delivering the washed coal as "trebles" (1¾ to 2¼ in.), "doubles" (1 to 1¾ in), "singles" (⅝ to 1 in.), and "pearls and gum" (below ⅝ in.). The various bunkers throughout the plant have the following capacity, with the figure in tons given in brackets: Raw coal feed hopper (55), trebles (35), doubles (35), singles (55), pearls (55), gum (two bunkers, total 110), and dirt (45), that is a total of 390 tons of bunkerage. Five electric motors are required with a total of 235 hp.

The results of this plant are particularly interesting the ash content of the raw coal being 6.58 per cent between ⅝ to 2¾ in. and 9.42 per cent below ⅝ in., which is a better quality coal than the average in Great Britain, although the moisture, 15 to 18 per cent, is very high. The raw coal is divided by the washing plant into the products listed in the following table which also gives the corresponding ash and moisture content based on a detailed test of 813 tons of coal:

Class	Size inches	Weight per cent of raw coal	Ash per cent	Moisture per cent
Trebles ...	2¾—1¾	6.6	6.50	12.53
Doubles ..	1¾—1	25.1	4.10	13.14
Singles ...	1 — ⅝	19.4	4.25	13.72
Pearls	⅝— ¼	22.5	3.85	14.26
Gum	¼—0	18.2	4.33	22.06
Shale	2¾—0	8.2(by diff.)	...	10.90

It will be seen the ash content was reduced to 3.85 to 6.50 per cent, say about 5 per cent, but later when more experience was obtained the range averaged 3.2 to 3.7 per cent, a highly satisfactory figure.

The largest Baum washer in Great Britain has been supplied by H. Greaves and Co., Ltd., of Derby to the Marine Colliery of the Ebbw Vale Iron Steel & Coal Co., Ltd., South Wales. This installation has a rated capacity of 300 tons of coal per hour, although an output of 360 tons has been obtained. It consists of two separate sections having in both cases rewashing boxes for the smalls. The installation has two centrifugal pumps each capable of delivering 4,500 gal. per min. against the maximum head, the cooling water requirements for the makeup being from 25,000 to 35,000 gal. per hr., while the slurry tank or silo of ferro-concrete is 50 ft. dia. and 60 ft. high.

The Specific Heat of Flue Gases

SPECIFIC heat may be given as instantaneous specific heat at a definite temperature or as a mean specific heat over a range of temperature. As the heat capacity of gases is usually considered as between two temperatures, the mean specific heat is of greater interest to engineers.

In the chart, Fig. 1, the specific heat of the principal constituent gases of flue gas is shown. The curves give the mean specific above 70 deg. fahr., at constant pressure.

In the chart, Fig. 2, the mean specific heat of flue gases from various fuels is given. The composition of the flue gases has been computed on the basis of 50 per cent excess air for all of the fuels except natural gas for which 25 per cent excess air has been assumed. The curves of Chart 2 have been constructed from data obtained from Chart 1 by multiplying the percentage by weight of each gas in the mixture by its specific heat and dividing the sum of the products by 100.

The composition of the flue gases of the various fuels as used in the calculation of the specific heats is given in Table 1 on the basis of percentage by weight. Normal moisture for each of the fuels has been assumed.

Although the curves give the specific heat above 70 deg. fahr., the heat capacity between any two temperatures may be obtained by determining the total heat above 70 deg. fahr., for each temperature and subtracting the two values.

TABLE 1—COMPOSITION OF FLUE GAS FOR VARIOUS FUELS

Percentage by Weight

	Anthracite	Low Vol. Bituminous	High Vol. Bituminous	Illinois Bituminous	Sub-Bituminous (Colo.)	Lignite (Texas)	Fuel Oil	Natural Gas
Per cent Moisture in fuel	2.0	3.0	3.5	10.0	22.0	35.0	....	....
CO_2	18.65	17.35	17.20	16.67	17.18	16.80	14.40	9.95
O_2	7.28	7.25	7.24	7.20	7.02	6.90	7.35	3.59
N_2	72.66	72.20	71.90	71.70	69.82	68.60	72.73	77.55
H_2O	1.41	3.20	3.66	4.43	5.98	7.70	5.52	8.91
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

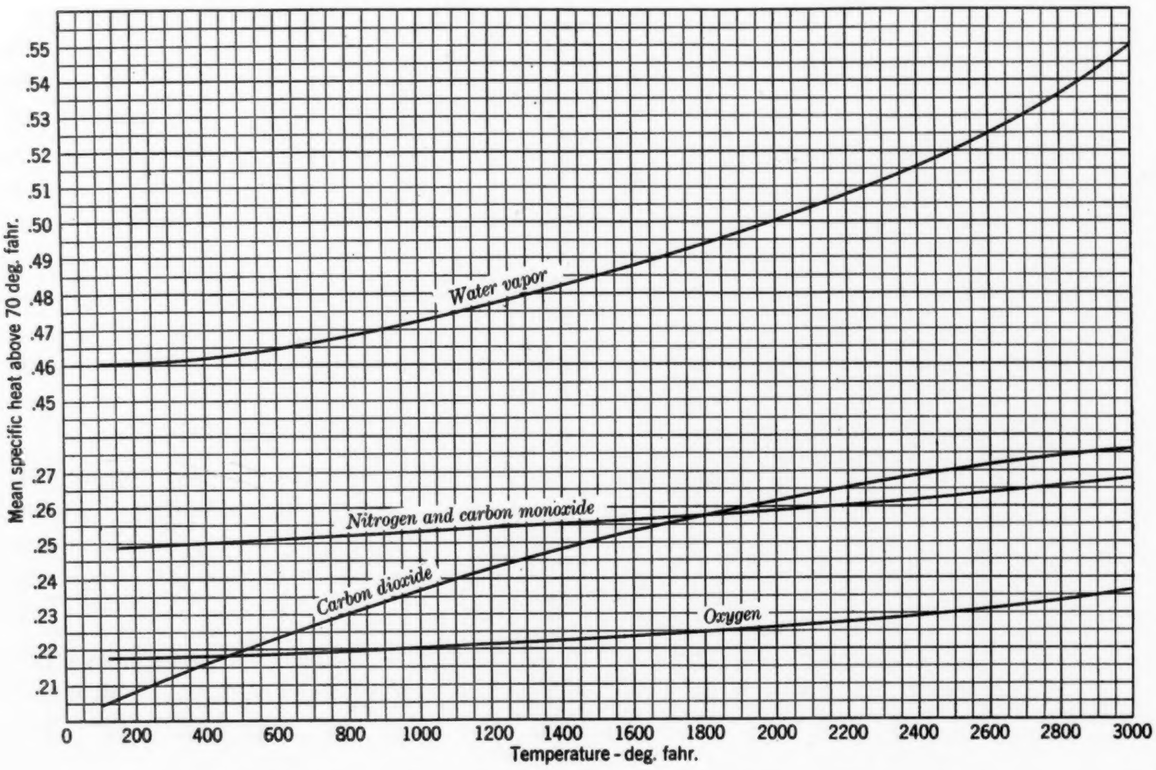

Fig. 1—Mean specific heat above 70 deg. fahr. of flue gas constituents.

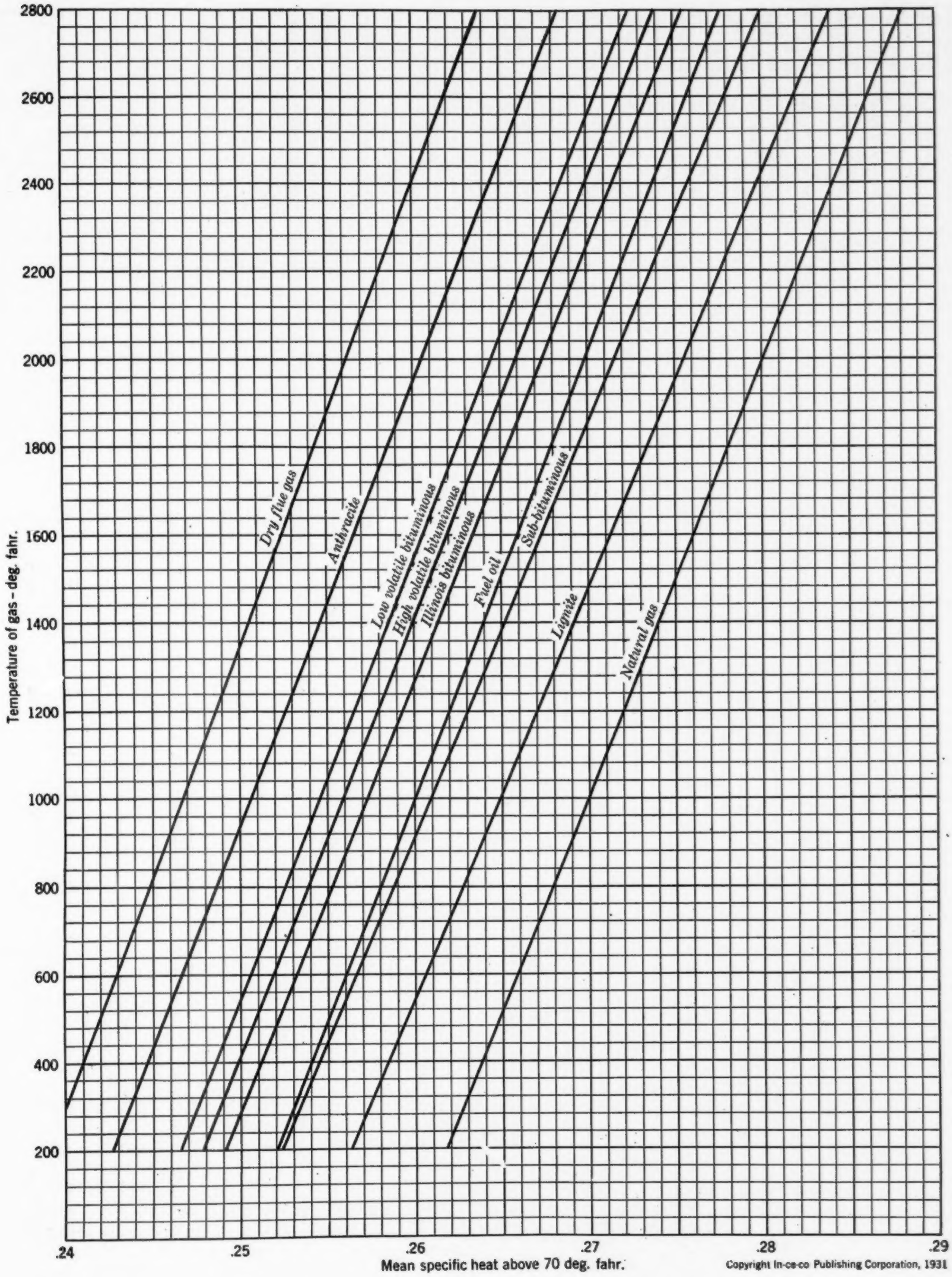

FIG. 2—CHART SHOWING MEAN SPECIFIC HEAT OF FLUE GASES FROM VARIOUS FUELS

No. 28 of a series of charts for the graphical solution of steam plant problems.

Tentative Program of International Bituminous Coal Conference

A tentative list of speakers and subjects for the Third International Conference on Bituminous Coal to be held at the Carnegie Institute of Technology, Pittsburgh, November 16 to 21, has been announced by Dr. Thomas S. Baker, organizer of the meetings and president of the institution sponsoring it.

The preliminary program contains the names of almost 100 speakers who will contribute to the world meeting. The papers have been classified into twelve major sections.

Seventeen countries will be represented in the conference, and an attendance of well over 2,000 persons is expected. The desperate plight of the coal industry has added impetus to the meeting, and the organizers feel that the conference comes at an appropriate time.

A partial list of the papers to be presented, divided according to sections, follows:

CLEANING AND PREPARATION

C. Berthelot, France—Methods of Coal Washing with Particular Reference to Fine Coal; Byron M. Bird, United States—Interpretation of Float-and-Sink Data; Dr. I. L. Blum, Roumania—The Role of Huminic Acids in the Briquetting of Brown Coal; Prof. W. R. Chapman, England—Coal Cleaning Practice in Great Britain; Thomas Fraser, United States—The Air-Sand Process of Coal Cleaning; Prof. Dr. Karl S. Glinz, Germany—Impact Mills for the Manufacture of Powdered Coal; Prof. Dr. B. Granigg, Austria—Laboratory Experiments on Magnetic Coal Dressing; Prof. Dr. Hans G. Grimm—Recent Progress in the Refinement of Coal; Dr. Karl Lehmann, Germany—Preparation of Coal from a Petrographic Point of View; E. B. Ricketts, United States—Value of Clean Coal for Steam Production.

HYDROGENATION—LIQUEFACTION

Dr. Friedrich Bergius, Germany—Early History of Hydrogenation; Prof. A. Gillet, Belgium—The Dispersion of Coal in a Liquid Medium; J. Ivon Graham & D. G. Skinner, England—Further Investigations of the Action of Hydrogen upon Coal; André Kling & Daniel Florentin, France—Catalysts in Hydrogenation Cracking; Dr. Hans Tropsch, Czechoslovakia—Catalysts for High Pressure Reduction and Hydrogenation of Phenols and Hydrocarbons.

BY-PRODUCTS

Prof. Dr. H. Mallison, Germany—The Chemistry and Physics of Tar for Use in Road Construction; Prof. A. W. Nash, England—Synthesis of Lubricating Oils from Coal and Its Gaseous Products; Dr. L. V. Redman, United States—Subject to be announced later.

GASIFICATION

Dr. M. Barash & T. A. Tomlinson, England—Steaming in Continuous Vertical Retorts; Prof. Dr. M. Dolch, Germany—Tar Decomposition and Its Relation to Gasification; G. Egloff & A. Fisher, United States—The Simultaneous Cracking, Carbonization and Gasification of Coal and Oils; Prof. Dr. H. G. Grimm, Germany—Gasification of Coal in the Winkler Generator; Prof. Dr. J. Gwosdz, Germany—The Complete Gasification of Coal with Special Reference to the Utilization of the More Reactive Fuels for the Preparation of Hydrogen-rich Gases; N. E. Rambush, England—Large Capacity Water Gas Generators in Great Britain; L. H. Sensicle, England—Intermittent Vertical Chamber Ovens, Some Recent Developments; Prof. G. V. Slottman, United States—Improvements in Gas Producer Control; Dr. A. Thau, Germany—Production of Water Gas from Powdered Fuel.

COMBUSTION

Gas

Prof. Dr. E. Berl, Germany—The Formation and Combustion of Hydrocarbons.

Pulverized Coal

E. G. Bailey & R. M. Hardgrove, United States—The Slag Tap Furnace and Its Effect upon the Selection of Coal for Pulverized Coal Firing; André Grebel, France—Study of the Mechanism of the Combustion of Pulverized Coal; R. Pawlikowski, Germany—Progress of the Coal-Dust Motor; R. A. Sherman, United States—An Experimental Study of the Process of Combustion of Pulverized Coal; Ch. M. Stein, France—High Speed Pulverizers for Use in Cement Kiln Firing; T. Suwa, Japan—Combustibility of Powdered Coal as Fuel for the Coal Dust Engine; E. H. Tenney, United States—Theoretical and Practical Aspects of Pulverized Coal Firing.

Coal and Coke

Dr. S. P. Burke, United States, and Dr. T. E. W. Schumann, South Africa—The Mechanism of Coal Combustion; Bert Houghton, United States—The Burning of Bituminous Coal on Large Underfeed Stokers; Harald Nielson, England—High Combustion Densities in Restricted Furnace Space; F. Schulte, Germany—Development of Grate Firing in Germany.

(*Continued on page 53*)

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Hydrogen Ion Determinations in the Steam Plant

(*Continued from page 39*)

in the following tabulation the pH value of the coagulated water is appreciably lower than the raw water due to the addition of the coagulant. It also indicates by the color standards that clarification is satisfactory. The increase in pH value in the filtered water is due to the addition of alkali while the progressive increase to the boiler feed is due to the zeolite softener and deaerator respectively. The effect of concentration and decomposition of sodium carbonate is reflected in the boiler water by its relatively high pH value while the pH value of the condensed steam indicates acidity due to CO_2 generated in the boiler.

Water Samples

	Raw	Coagulated	Filtered	Softened	Deaerated Boiler Feed	Boiler	Cond. Steam
pH	7.4	6.6	6.8	7.0	8.0	11.2	6.4
Color	15.	10.	0	...	...	...	...
Total alkalinity as $CaCO_3$ (p.p.m.)	25.7	13.7	15.4	20.6	20.6	...	...
Sodium hydrate (p.p.m.)	...	...	...	...	...	103	...
Sodium carbonate (p.p.m.)	...	...	...	...	...	77.7	...
Sodium chloride (p.p.m.)	...	...	...	...	...	170	...
Sodium sulphate (p.p.m.)	...	...	...	...	...	68.5	...
Oxygen cc./liter	...	...	...	...	0.5	...	...

By the maintenance of sample records such as this together with the observation of the effect of these waters on equipment, the processes of filtration and softening, the engineer determines the best condition to maintain and the records will show any deviation from this standard which can be corrected promptly, for just as meters give the engineer valuable data concerning the quantities of material he is using so the pH value gives him the quality of water as pertains to acidity and alkalinity.

NEWS

Pertinent Items of Men and Affairs

Pulverized Coal Shipped by Pipe Line

The Lehigh Navigation Coal Company, engineers, are reported to be experimenting with the transportation of pulverized anthracite by pipe line as a means of reducing transportation costs.

Reports of the experiments indicate that the engineers have developed a method of pulverizing the smaller sizes of anthracite and of moving the coal in a semi-liquid state through a pipe line for a considerable distance and drying it at destination.

Particular interest in the success of the present experiment was created by the proposed 15 per cent horizontal freight rate increase asked by the railroads. The anthracite coal operators believe that rates on coal are already excessive and that an increase will seriously handicap the industry.

American Blower Buys Factory Site

The purchase of a seventeen acre tract of ground at Detroit, Michigan, for the future home of the American Blower Corporation has been announced.

Although neither plans nor construction work will be started at present, probably not until some time in 1932, it is the purpose of the American Blower Corporation, according to C. T. Morse, vice-president, to erect on this site a new and thoroughly modern plant for the manufacture of air handling apparatus of all kinds.

•

Northern Equipment Company, manufacturer of Copes Feedwater Regulators and allied equipment, has announced that W. J. McDonough has joined its engineering staff and will be located at Erie, Pennsylvania.

•

The Dampney Company of America, manufacturer of protective coatings for metal surfaces, Hyde Park, Boston, Massachusetts, has appointed Clarence J. Hunter general sales manager, with headquarters at the Hyde Park general office. Mr. Hunter was formerly manager of the Philadelphia branch office of the Dampney Company.

•

Bailey Meter Company, Cleveland, Ohio, has announced the location of sales engineers in two southern cities. M. J. McWhorter continues as manager of the Southern territory but has moved his headquarters from Atlanta, Georgia, to a new office at 1708 Euclid Avenue, Charlotte, North Carolina. J. H. Whittlesey will be located at 3201 Carlisle Road, Birmingham, Alabama.

Coal Use is Cut by Competition Survey Reveals

The use of coal as a source of energy has declined in favor of other means, although still maintaining its position as chief source of energy, the National Industrial Conference Board reveals in a study just published. In 1913 coal produced 88 per cent of the total world energy reduced to terms of equivalent coal but since that time the ratio has steadily declined to 74 per cent in 1929 and 72 per cent in 1930. The decline is due to several causes, the survey says, but primarily to the rapid expansion in the use of oil products, principally motor fuels and fuel oils.

A study of fuels and sources of energy, involving more than two years of work by the research staff of the board, has just been completed and will shortly be published under the title "Competitive Factors in World Energy." The report reveals the tremendous changes that are taking place in the world through the rapid introduction of new sources of energy and the constant improvement in the efficiency of both old and new sources.

"In contrast with the decline in the proportionate use of coal the oil group has increased from only 6 per cent of the total world energy demand in 1913 to 17 per cent in 1929 and 19 per cent in 1930," the survey states. "Stated in terms of quantity this is an increase in world consumption of fuel oil from about 220,000,000 barrels in 1913 to 660,000,000 barrels in 1930 and of motor fuel from about 40,000,000 barrels in 1913 to 555,000,000 barrels in 1930.

"Fuel oil, however, has been the most direct competitor of coal because it is primarily used for the same purposes. In 1913 there was little use of fuel oil outside the United States, Russia and other oil producing countries. The disturbed conditions in the world fuel markets during the World War, together with increasing supplies of crude oil in Mexico, Asia and the United States, led to the introduction of fuel oil into many new world markets. The period of greatest expansion has been since 1923. Since that time the development of the use of fuel oil for ships represents one of the most important items of competition with coal.

"The average annual world coal consumption for 1927, 1928 and 1929," continues the survey, "was approximately 1,492,000,000 short tons, lignite coals being reduced to terms of bituminous coal equivalent. This represents a gain of only 110,000,000 tons over the consumption of 1,382,000,000 in 1913, the maximum pre-war year. Since the total consumption of all forms of energy, in terms of coal equivalent, increased by about 430,000,000 tons in the same period, it is evident that coal demand was greatly retarded by the development of competing forms of energy, and that such increase as took place was limited to countries or parts of countries where coal is the dominant fuel."

NEW CATALOGS AND BULLETINS

Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Automatic Stoker Control

New Bulletin No. A-14 presents the Mercoid Automatic Control for stokers and forced draft coal burning equipment. While this type of control is designed particularly for the smaller type installations, it is also applicable to general industrial use. The folder illustrates and describes the apparatus in detail, and specifications and price lists are included, together with suggested application diagrams. 8 pages, 8½ x 11—The Mercoid Corporation, 4201 Belmont Avenue, Chicago, Ill.

Dust Collectors

The construction, operation and application of the Vorticose Dust Collector are described in a new bulletin. This collector employs the four outstanding principles of mechanical dust collection; projection, concentration, precipitation and settlement. The apparatus is suited to a broad field of application including power plants and the general industrial application where dust demitations have heretofore been a problem. 16 pages and cover, 8½ x 11—Dust Recovery, Inc., 15 Park Row, New York, N. Y.

Electric Stoker Drive

The C-E Electric Drive which is applicable to both Type E and Type K Underfeed Stokers is described in a new folder. This drive consists of a constant speed a.c. or d.c. motor operating the driving mechanism through a gear box containing a double worm drive. The unit includes a unique timing device for automatically changing the number of strokes per minute. The gears are totally enclosed and run in oil. The salient features of this drive are illustrated and described and reference is made to the wide application of the two types of stokers to which this drive is applicable. 4 pages, 8½ x 11—Combustion Engineering Corporation, 200 Madison Ave., New York, N. Y.

Feed Water Regulator

The Lindstrom Automatic Feed Water Regulator for low pressure boilers is illustrated and described in a new folder. This regulator is very simple and is composed of only six parts. The regulator provides a continuous feed while the boiler is in service and maintains the water level between predetermined limits. There are no springs and no stuffing boxes employed. 4 pages, 4 x 9—Strom-Port Manufacturing Co., Inc., 215 South Third St., Allentown, Pa.

Gas Burning Equipment

A handsome new catalog illustrates and describes the complete line of Webster Gas Burners and auxiliary equipment. The equipment shown is applicable to all types of boilers, stills, kilns and dryers. The use of radiant material for protecting metal parts from the heat of the furnace is one of the salient features of Webster burner design The catalog includes a wealth of engineering information, charts, diagrams, application drawings and details of equipment. It is attractively bound in loose covers. 120 pages and covers, 8½ x 11—Surface Combustion Corporation, Toledo, Ohio.

Heat Exchangers

The Schutte & Koerting Polyplate Heat Exchangers are described in bulletin 12-H Supplement 1. This device is a surface heat transfer apparatus adapted to the handling of water, oils and other liquids, as well as steam, air and gases. The outstanding feature of the polyplate design is the absence of tubes and tube sheets, the unit consisting simply of two headers and a set of circular plates fastened together with through-bolts. The liquids pass through the exchanger from plate to plate in counterflow, the transfer of heat taking place through the plate walls. 2 pages, 8½ x 11—Schutte & Koerting Company, Philadelphia, Pa.

Materials Handling Pumps

Catalog No. 331 describes the Hydroseal Pump which is built to provide an efficient means for handling ash laden water without the discharge pressure limitations and excessive maintenance costs which are inherent in pumps ordinarily employed for this use. The Hydroseal Pump is not built along conventional lines. The standards of materials and workmanship are definitely superior to those formerly adopted in this class of equipment. The features of design and details of construction are well illustrated and an impressive list of users is included. 12 pages, 8½ x 11—Allen-Sherman-Hoff Company, Philadelphia, Pa.

Mechanical-Drive Turbines

New bulletin GEA-1450 describes the General Electric Mechanical-Drive Turbine Type D-58. These turbines are of the non-condensing type and are used to drive pumps, blowers and similar steam plant auxiliaries. The turbine is available for steam pressures up to 400 lb. and steam temperatures up to 750 deg. fahr. The features of design are indicated in both photographs and line drawings. 4 pages, 8½ x 11—General Electric Company, Schenectady, N. Y.

Protective Coatings

"Bitumastic Special Protective Coatings for Industry" is the title of a new bulletin which describes 50 years of successful experience in protecting metal surfaces from corrosion. The application of protective coatings is available to a wide range of structures, including coal and ash bunkers, tanks, standpipes and pipe lines for gas, oil and water. Many application arrangements are illustrated and described. 8 pages and cover, 8½ x 11—Wailes Dove-Hermiston Corp., 17 Battery Place, New York, N. Y.

Refining Equipment

Foster Wheeler petroleum refining equipment is presented in a new bulletin which is complete with illustrations of installations made in practically every part of the world. The photographs are particularly well chosen and reproduced and the bulletin is handsomely bound in a loose leaf folder. 56 pages and cover, 8½ x 11—Foster Wheeler Corp., 165 Broadway, New York, N. Y.

Refractory Cement

PYRO-MORTAR, a new dry refractory cement, is presented in bulletin PM-301. This material is a dry cement for bonding fire brick, for plaster coatings, for pointing up cracks and reclaiming eroded furnace walls and similar applications. The series of illustrations show the correct method of mixing and applying this new refractory cement. 4 pages, 8½ x 11—Quigley Company, 56 West 45th St., New York, N. Y.

Water Testing Equipment

An interesting and valuable bulletin has just been issued by the National Aluminate Corporation, who present a complete line of water testing equipment for laboratory and power plant use. Following descriptions and illustrations of the apparatus, there is a chapter devoted to instructions for making water tests. 12 pages and cover, 8½ x 11—National Aluminate Corp., 6216 West 66th Place, Chicago, Ill.

Welding Fittings

A new line of Midwest Welding Fittings is described in folder WF-2. A complete line of fittings is available, including 45° and 90° cells, heads, saddles and sleeves. Each Midwest welding ell is made from one piece of plate by a special process which provides the final working of the metal in compression at a forging heat. Dimension tables are reputed covering welding fittings for a wide range of stand pipe size. 4 pages, 8½ x 11—Midwest Piping & Supply Co., 1450 So. Second St., St. Louis, Mo.

NOTICE

Manufacturers are requested to send copies of their new catalogs and bulletins for review on this page. Address copies of your new literature to

COMBUSTION

200 Madison Ave., New York

NEW EQUIPMENT

of interest to steam plant Engineers

Pipe Welding Fittings

A new line of welding fittings—ells, saddles, sleeves and heads has been placed on the market by Midwest Piping and Supply Company, St. Louis, following 2 years of research, experimental work and testing.

These fittings represent an important development because they reduce the cost

of many types of piping systems in addition to improving the systems themselves.

Of primary importance are the dimensional accuracy and uniformity of these welding fittings which are made to exact radius and sectional diameter and in perfect round as a result of a special compression sizing operation that has been developed by Midwest. Unique fixtures used in machining the bevel on the ends of the fittings and assure and include angles of exactly 90° or 45°. Midwest welding ells are tangents—an important feature because they reduce the time and cost of installation since they make it possible to line up the piping and fitting quickly and accurately. One-quarter inch of tangent is provided for each inch of pipe diameter; thus an 8 in. ell has tangents 2 in. long at each end. Each Midwest welding ell is made from one piece of plate by a special patented process. There is but one welded longitudinal seam along the inner circumference.

The welds are so located as to be accessible and are removed from the point of maximum piping stress. The final working of the metal is in compression at a forged heat—thus normalizing and refining the metal in the wall and in the weld—it is neither extruded nor stretched.

The accompanying illustration shows 45° and 90° ells. These fittings are available in a complete range of standard stock sizes.

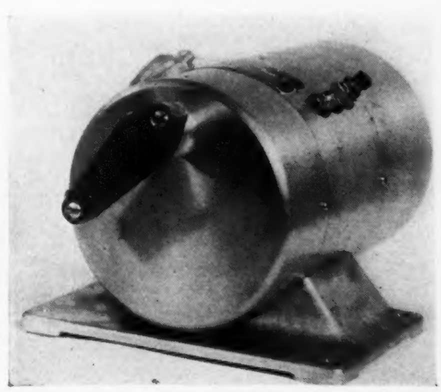
Proportioning Control System

The demand for a control to meet the needs of modern industry has been responsible for the development by the Minneapolis-Honeywell Regulator Company, Minneapolis, Minnesota, of a new and radically different control system.

Practically all motor operated valve control systems have been of the "off and on" type, or modifications of it. These modifications have usually been some form of step control, used to effect continuity of supply of heat and to meet variations in demand. However, if temperatures are to be controlled accurately, heat must be supplied not only continuously but also graduated in proportion to the need for it.

Proportioning implies an equality of ratios. For example, if the movements of a damper are graduated so that its degrees of opening are proportional to temperature variations, we will have established a relationship in which the ratios are direct. The Minneapolis-Honeywell Proportioning Control does just this through the medium of electrically controlled units. The apparatus incorporates a combination of two parts, namely the electrical transmission system and the associated power unit which can be adjacent to or remote from the controlling instrument. A mechanical interconnection is required between the power unit and the electrical balancing mechanism. The transmission system operates on the Wheatstone Bridge principle.

The power unit, inherently a motor driven speed reducer, causes its drive shaft to take a new position whenever the conditions under control, such as temperature, change slightly. If a device such as a valve, or valves, louvers or rheo-



stats are driven by the motor, then their operation tends to correct the change and a condition of equilibrium is approached. The result is that an amazingly constant control of temperature, pressure, humidity, liquid level, rates of flow, stoker or pulverizer feed, etc., can be attained.

A notable feature is that the motor operates only when a change of position is demanded by the controller. Then the driven devices are moved immediately to a new position and remain there until conditions again change. This means that the demand for electrical energy occurs only during the repositioning period whereupon the motor starts in either direction with maximum torque available to move the driven device to a new position.

A further advantage of the Proportioning Motor Control System is that the magnitude of the response to a given deflection of the controlling instrument may be made as great or small as desired. In addition this response may be made to vary automatically with relation to the existing and the desired condition.

New Self Leveling Burette for Water Analysis

An improvement in self leveling burettes has been placed on the market by the National Aluminate Corporation, 6234 West 66 Place, Chicago. The advantages of this burette over its predecessor are its extreme simplicity and compactness.

The new burette, which is shown in the accompanying illustration, is 16½ in. high and the reservoir has a capacity of 500 cubic centimeters. Various reservoirs

are available with suitable markings for soap, acid and silver nitrate. For the latter solutions a brown bottle is used in order to keep out the light.

The burette itself contains 10 cubic centimeters. This new device is now standard equipment in all of the water testing kits distributed by the National Aluminate Corporation with the exception of the traveling kit.

This new burette will find ready application to feedwater analysis.

Boiler, Stoker and Pulverized Fuel Equipment Sales

BOILER SALES

Orders for 816 boilers were placed in July according to reports submitted to the Bureau of the Census by 73 manufacturers.

Month	1930		1931	
	Number	Square feet	Number	Square feet
January	942	1,081,749	598	576,723
February	873	938,906	516	622,343
March	977	1,263,709	630	664,784
April	1,017	1,070,093	689	825,203
May	1,283	1,329,748	658	603,401
June	1,360	1,588,553	818*	677,434*
July	1,309	1,410,096	816	687,058
Total (7 mo.)	7,761	8,682,854	4,725	4,656,946
August	1,371	1,356,751		
September	1,254	1,282,388		
October	1,189	851,525		
November	777	709,322		
December	814	587,053		
Total (Year)	13,166	13,469,893		

* Revised.

Totals for First 7 Months and New Orders, by Kind, Placed in July, 1930-1931

Kind	1930		1931		July, 1931	
	No.	Sq. ft.	No.	Sq. ft.	No.	Sq. ft.
Stationary: Total	7,761	8,682,854	4,725	4,656,946	816	687,058
Water tube	702	3,600,114	449	1,936,988	87	297,636
Horizontal return tubular	563	767,632	300	375,060	45	56,990
Vertical fire tube	754	233,502	384	106,999	55	19,194
Locomotive, not railway	115	96,902	63	56,633	4	1,664
Steel heating	4,368	1,980,262	2,921	1,330,560	561	246,001
Oil country	702	805,118	278	312,616	33	37,375
Self contained portable	283	195,236	174	119,537	29	26,808
Miscellaneous	89	54,680	37	21,230	1	119

MECHANICAL STOKER SALES

July stoker sales, reported to the Bureau of the Census by the 11 leading manufacturers, totaled 101 stokers of 20,735 hp.

Year and Month	TOTAL		INSTALLED UNDER Fire-tube boilers		INSTALLED UNDER Water-tube boilers	
	No.	H.P.	No.	H.P.	No.	H.P.
1929						
Total (First 7 mo.)	998	358,418	379	57,841	619	300,577
Total (Year)	1,716	599,585	706	102,515	1,010	497,070
1930						
January	53	13,198	24	2,872	29	10,326
February	73	22,648	26	3,732	47	18,916
March	89	32,403	45	6,128	44	26,275
April	108	35,903	46	6,984	62	28,919
May	96	31,956	41	5,703	55	26,253
June	151	47,803	70	10,100	81	37,703
July	150	37,761	83	11,434	67	26,327
Total (7 mo.)	720	221,672	335	46,953	385	174,719
August	115	29,988	61	10,587	54	19,401
September	128	42,899	71	9,186	57	33,713
October	92	38,276	46	5,148	46	33,128
November	71	21,103	41	5,731	30	15,372
December	53	11,726	35	5,307	18	6,419
Total (Year)	1,179	365,664	589	82,912	590	282,752
1931						
January	85	25,902	40	6,719	45	19,183
February	67	14,249	37	5,326	30	8,923
March	63	17,993	27	4,509	36	13,484
April	65	18,723	32	5,192	33	13,531
May	80	23,646	29	4,341	51	19,305
June	111	29,889	55	8,519	56	21,370
July	101	20,735	58	8,283	43	12,452
Total (7 mo.)	571	150,737	278	42,889	293	107,848

PULVERIZED FUEL EQUIPMENT SALES

July orders for coal pulverizers as reported to the Bureau of the Census aggregated 16 pulverizers having a total capacity of 118,500 lb.

Year and Month	STORAGE SYSTEM — PULVERIZERS: Total Number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb. coal/hr. for contract	STORAGE SYSTEM — BOILERS: Number	Total sq. ft. steam generating surface	Total lb. steam per hour equivalent	DIRECT FIRED OR UNIT SYSTEM — PULVERIZERS: Total Number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb. coal/hr. for contract	DIRECT FIRED OR UNIT SYSTEM — BOILERS: Number	Total sq. ft. steam generating surface	Total lb. steam per hour equivalent
FOR INSTALLATION UNDER WATER-TUBE BOILERS														
1931														
January	2	2	..	60,000	1	51,177	704,000	8	4	4	40,500	9	42,970	412,675
February	1	..	1	40,000	1	29,100	375,000	2	2	..	8,000	1	7,570	75,000
March	2	2	..	60,000	..	.....	......	13	13	..	122,000	8	93,960	1,404,000
April	2	2	..	60,000	1	34,300	592,000	9	8	1	49,250	6	46,300	538,200
May	..	..	..	.....	..	.....	......	..	..	..	.....	..	.....	......
June	..	..	..	.....	..	.....	......	14	6	8	59,360	11	56,080	530,290
July	..	..	..	.....	..	.....	......	11	8	3	114,600	8	117,000	1,088,980
Total (7 mo.)	7	6	1	220,000	3	114,577	1,671,000	57	41	16	393,710	43	363,880	4,049,145
FOR INSTALLATION UNDER FIRE-TUBE BOILERS														
1931														
January	..	..	..	.....	..	.....	......	6	..	6	6,000	6	7,500	53,350
February	..	..	..	.....	..	.....	......	3	..	3	2,250	3	3,000	22,350
March	..	..	..	.....	..	.....	......	2	1	1	2,750	1	3,004	22,500
April	..	..	..	.....	..	.....	......	1	..	1	4,000	2	6,700	45,000
May	..	..	..	.....	..	.....	......	3	1	2	3,800	3	6,000	27,000
June	..	..	..	.....	..	.....	......	4	1	3	4,000	4	5,750	22,100
July	..	..	..	.....	..	.....	......	5	3	2	3,900	5	8,000	47,700
Total (7 mo.)	..	..	..	.....	..	.....	......	24	6	18	26,700	24	39,954	240,000

BOOKS

1
THE HIGH SPEED INTERNAL-COMBUSTION ENGINE

By Harry R. Ricardo

435 Pages Price $12.00

Covering every practical detail of design with full explanations and diagrams this book has been recognized for years as an outstanding authority and practical reference in this field It has been thoroughly revised to include all the great developments of the past few years, including the latest facts on Diesel Engines which have been fully presented and illustrated by many practical diagrams and photographs of actual installations. *Chapter headings:* Volatile Liquid Fuel for Internal-Combustion Engines; Detonation; Distribution of Heat in a High-Speed Four-Cycle Engine; Influence of Form of Combustion Chamber; Lubrication and Bearing Wear; Mechanical Design; Mechanical Details; Valves and Valve Gear; Piston Design; Engines for Road Vehicles; Aero-Engines; High-Speed Heavy-Duty Engines for Tanks; High-Speed Diesel Engines.

2
FUELS AND THEIR COMBUSTION

By Robert T. Haslam and Robert P. Russell

807 Pages Price $7.50

A thorough treatise on the origin, composition and production of fuels and their efficient utilization. The book presents the underlying principles of the science of combustion, describes typical combustion equipment, gives actual plant data, explains common combustion reactions and discusses the flow of air and flue gases and heat transfer. It summarizes the latest investigations and developments in the field of combustion engineering. The authors were formerly professor of chemical engineering and assistant professor of chemical engineering, respectively, Massachusetts Institute of Technology.

3
FINDING AND STOPPING WASTE IN MODERN BOILER ROOMS

808 Pages Price $3.00

This well known Cochrane reference book has been revised and enlarged. New matter has been introduced in the sections on Fuels, Combustion and Heat Absorption, and considerable material has been added on the subjects of steam and water measurements, water treatment and testing. As a handbook on these subjects, this volume is eminently practical and useful. Every steam plant engineer should have a copy. The third edition is being rapidly depleted. To assure your getting a copy without delay, send your order immediately.

4
BURNING LIQUID FUEL

By William Best

341 Pages Price $4.00

This volume is a practical treatise on the perfect combustion of oils and tars, giving analyses, calorific values and heating temperatures of various gravities with information on the design and proper installation of equipment for all classes of work. It contains many illustrations of installations in successful operation, many of which show the interior construction of the equipment and reveal the most modern application of liquid fuel so as to obtain practical combustion. Twenty of the chapters are devoted to particular oil fuel burning equipment for many different industries including commercial gas, sugar, steel, heat treating, iron and brass, forge shop, boiler makers, enameling, chemical industry and many others.

5
CONDENSED ENCYCLOPEDIA OF ENGINEERING

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6
THE FLOW OF HOT GASES IN FURNACES

By W. E. Groume-Grjimailo

399 Pages Price $5.50

This is a particularly informative and authoritative reference on the subject of combustion gases. Its contents include a practical discussion of the principles for the rational construction of furnaces. The reading and study of this valuable book should lead to many improvements in the art of heating and utilizing of heat.

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Tentative Program of International Bituminous Coal Conference

(*Continued from page 46*)

CARBONIZATION

Dr. H. C. Porter, United States—Varying Flow Property of Coals in the Softened State; Prof. R. V. Wheeler & Dr. J. H. Scholtz—Carbonization of Bituminous Coal in Streams of Gases; Prof. Wheeler & R. A. Mott, England—Blending of Coals for Coke Making.

Low Temperature

C. M. Ab-der-Halden, France—Continuous Low Temperature Distillation in a Rotating Hearth Furnace; P. C. Pope, England —Present Status and Future Prospects of Low Temperature Carbonization in England; F. Puening, United States—Low Temperature Carbonization; Dr. R. P. Soule, United States—Lessons from Low Temperature Carbonization.

High Temperature

Dr. K. Baum, Germany—Fuel Economy in German Coke Plants; C. Berthelot, France—European Progress in the Technique of Coal Carbonization; A. C. Fieldner & J. D. Davis, United States—The Relation of Chemical and Physical Tests of Coal to Coking Properties and By-Product Yields; John Roberts, England—Blending: with Special Reference to the Davidson Rotary Retort; Prof. P. Schlaepfer, Switzerland—Influence of the Various Constituents o fCoal on Its Swelling and Coking Power; Dr. G. Stadnikoff, U.S.S.R.—General Considerations on the Fusibility and Coking of Bituminous Coals; Dr. Ernst Terres, Germany—Coke Formation; Prof. R. V. Wheeler & T. G. Woolhouse, England—Effect of Oxidation of the Coking Properties of Coal; Prof. Dr. J. P. Wibaut, Holland —On the Forms of Sulphur and Nitrogen in Coke and On the Fixation of Sulphur and Nitrogen by Amorphous Carbons at High Temperatures.

Domestic

A. R. Mumford, United States—Subject to be announced later; G. A. Young and W. T. Miller, United States—Studies of Small Stokers for Bituminous Coal.

RAILWAY AND STEAMSHIP FUEL

J. C. Chapple, United States—Pulverized Coal for Locomotives; C. J. Jefferson & R. D. Gatewood, United States—Use of Coal on Shipboard; Richard Roosen, Germany—Dynamometer and Road Results with Stug Pulverized Fuel Fired Locomotives; Ch. M. Stein, France—European Progress in the Use of Powdered Coal in Steamships; F. M. Waring, United States—Future Use of Coal as Locomotive Fuel; H. C. Woodbridge and Associates, United States—Railway Fuel.

SMOKE ABATEMENT, DUST REMOVAL AND FLUE GAS PURIFICATION

V. J. Azbe, United States—Rationalizing Smoke Elimination Methods; C. H. Desch, England—Prevention of Smoke in Metallurgical Operations; Dr. H. F. Johnstone, United States —The Elimination of Sulphur Compounds from Boiler Furnace Gases.

ORIGIN, CLASSIFICATION AND PROPERTIES

A. deAlvarado & L. M. Puget, Spain—Bituminous Layers in the Coal Basin of Puerta Llano, Spain; Hilding Bergström, Sweden—Spontaneous Ignition of Wood & Origin of Fusain; Prof. Dr. Ernst Berl, Germany—The Origin of Coal, Artificial Production of Substances Similar to Bituminous Coal and Petroleum.

ORIGIN, CLASSIFICATION AND PROPERTIES

Dr. Hans Bode, Germany—Classification of Coals; Dr. Franz Fischer, Germany—Biology and Coal; Dr. E. S. Grumell, England—Classification of British Coals; H. G. A. Hickling, England—Subject to be announced later; H. J. Rose, United States—Coal Classification; Prof. D. Wieluch, Poland —The Chemical Nature of Coal and the Theory of Coal Formation.

COMPETITION OF COAL WITH OTHER FUELS

Ford, Bacon & Davis Representative, United States—Subject to be announced later; R. B. Harper, United States—Competition Between Natural Gas and Coal; G. A. Orrok, United States—Economics of Water Power versus Steam Power; Dr. W. T. Thom, Jr., United States—The Interrelationships of Coal, Petroleum and Natural Gas.

ECONOMICS

F. G. Clark, Canada—Industrial Use of Off-Peak Power; W. H. Young, United States—Subject to be announced later.